Instruments

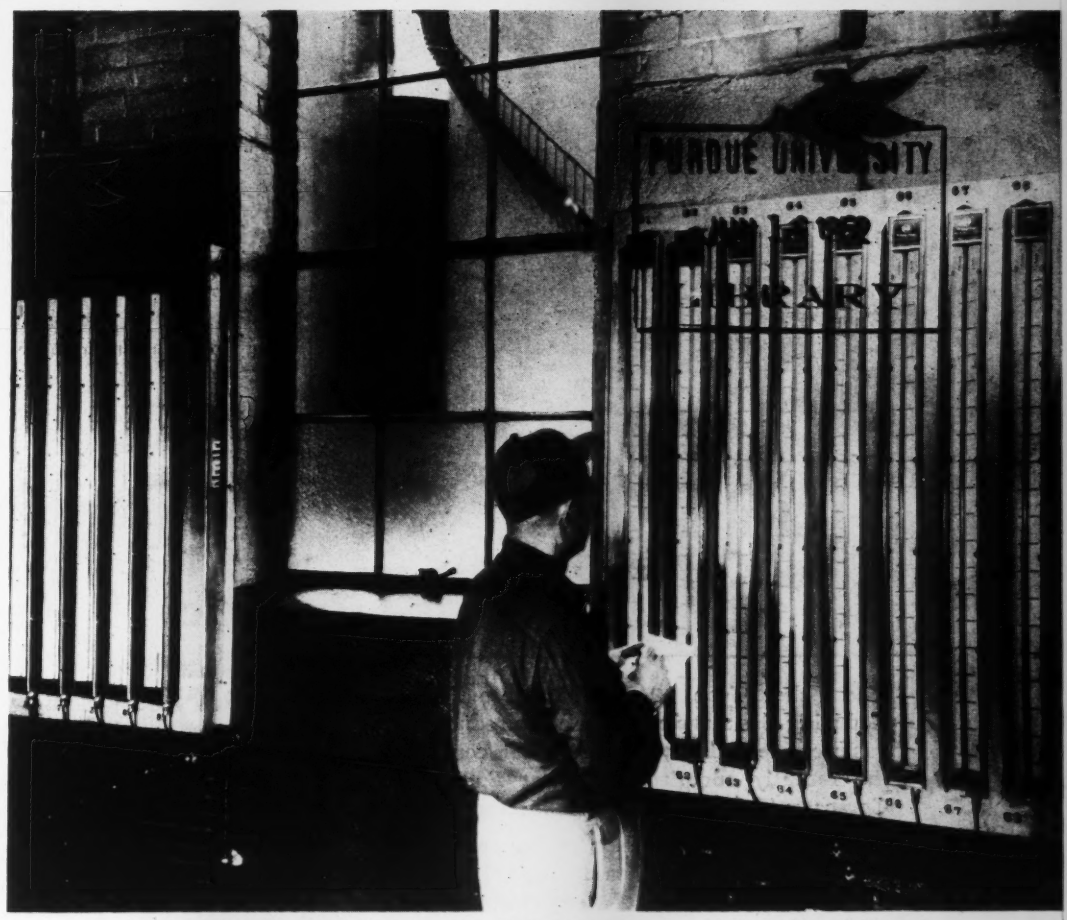
THE MAGAZINE OF MEASUREMENT
INSPECTION · TESTING · CONTROL

cluding the
JOURNAL OF THE INSTRUMENT SOCIETY OF AMERICA
d the
JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

this issue . . .

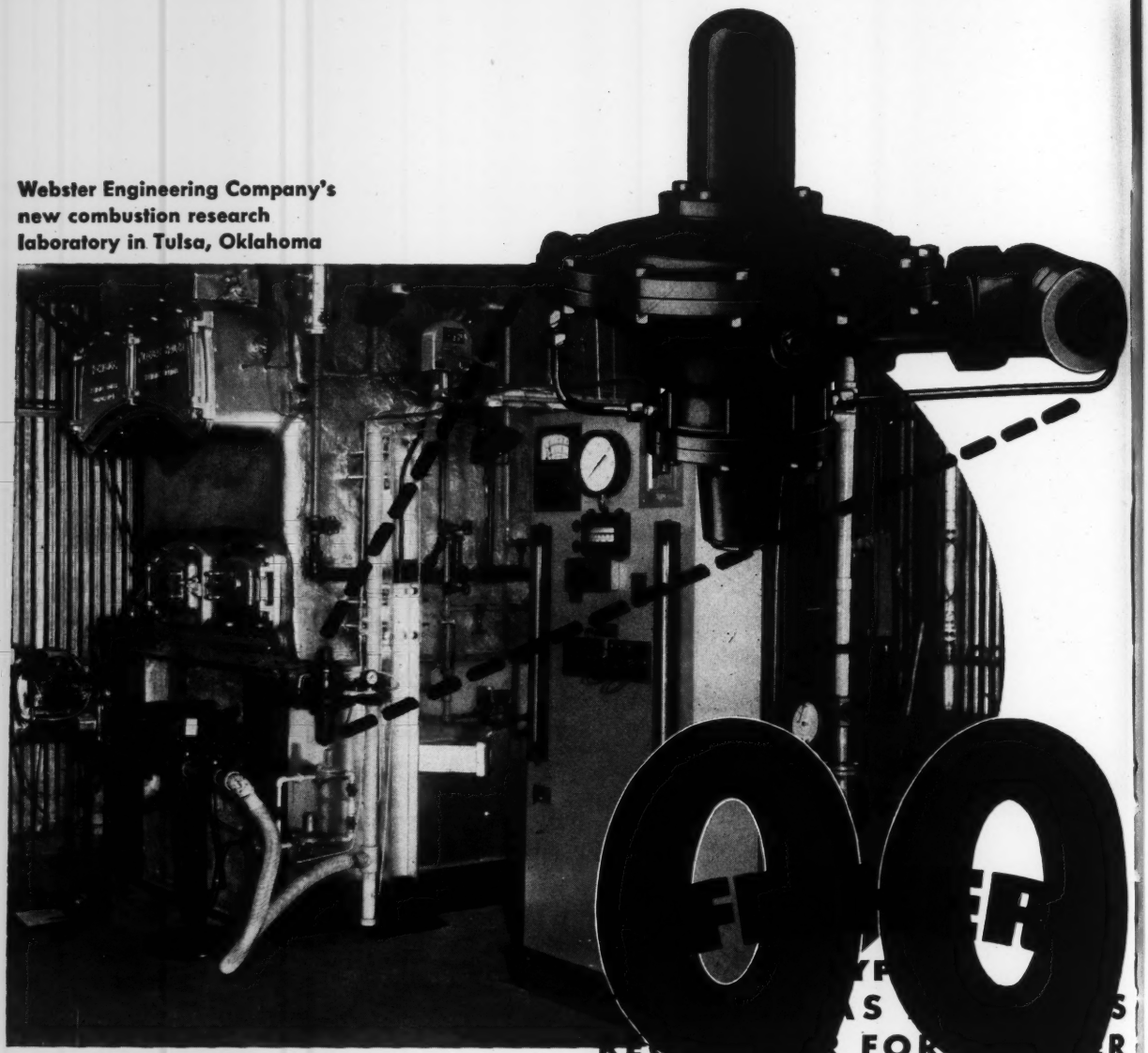
Valve-sizing Methods
A-c. Measurements
Automatic Control
Bismuth Thermocouples
Smoke Measurement
Data Plotting Machine
Instrument Electronics
Distillation Process Control System
Servo Techniques in Process Control
Gas Measurement Committee Report
96 New Instruments
120 New Bulletins

Vol. 25 No. 6
JUNE • 1952



Many banks of hydrostatic gages permit easy inventorying of 54-ft.-high field tanks at the Grease & Compounding Dep't, Socony-Vacuum Oil Co. Refinery, Trenton, Mich. See story on page 674. *(Photo courtesy King Engineering Corp.)*

Webster Engineering Company's new combustion research laboratory in Tulsa, Oklahoma



99

FOR ENGINEERING COMPANY'S NEW LABORATORY

The Fisher Type 99 Multi-Purpose Pressure Reducing Gas Regulator is used to reduce main gas pressure to the other combustion controls in the recently completed Webster Engineering Company, Tulsa, Oklahoma, laboratory.

Exclusively devoted to fact finding and capable of handling gas or oil under complete instrumentation, this laboratory is enabling WEBSTER to determine with complete accuracy the operating characteristics and efficiency of fuel burning and automatic control equipment up to an input of 5,000,000 Btu/hr.

FISHER GOVERNOR COMPANY
MARSHALLTOWN, IOWA

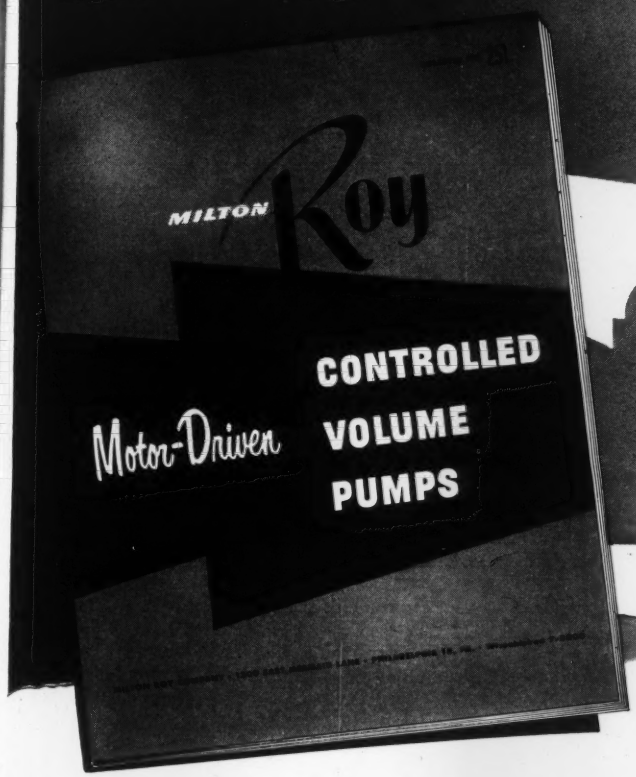
TYPE 99 SPECIFICATIONS

- **CAPACITY—**
  99,000 CFH at 100 PSI inlet pressure.
- **VERSATILITY—**
  For engine fuel systems, for industrial installations, and for low or intermediate pressure gas distribution systems.
- **PILOTS—**
  Low Pressure — 3 springs — 4 oz. to 2 PSI;
  2 PSI to 10 PSI;
  10 PSI to 20 PSI.
  High Pressure.....10 PSI to 65 PSI.

FISHER

LEADS THE INDUSTRY IN RESEARCH FOR BETTER GAS PRESSURE CONTROL

Motor-Driven CONTROLLED VOLUME PUMPS



Complete Information In These Pages

What *are* Milton Roy Motor-Driven Controlled Volume Pumps? What materials do they pump? How and where are they used? What different designs and models are available?

The answers to these questions and many more can be found in Bulletin No. 251. This illustrated, 24-page, 2-color bulletin is full of important details. Here is a preview of some of the subjects which are discussed:

- a description of various Milton Roy Motor-Driven Controlled Volume Pumps—the Simplex, Duplex, Constametric, "Titronic," and "miniPump."
- an explanation of the exclusive Milton Roy Liquid End Step-Valve design. This information is useful because it describes the "how" and "why" of this unique non-clogging, self-cleaning liquid end.
- a description of pump capacity regulation by *plunger stroke* adjustment, including screw adjustment, micro adjustment, motorized micro adjustment.
- details on pump capacity regulation by *plunger speed* adjustment, including speedranger adjustment, "Thymotrol" adjustment, Link Belt P.I.V. adjustment.
- data on where Milton Roy Motor-Driven Controlled Volume Pumps can be used.
- capacity-pressure selection tables are included.

If your operations call for pumping liquids in accurately measured volume in amounts as low as 3 milliliters per hour or as high as 50 gallons per minute, we're sure Bulletin No. 251 will be of value to you. For your free copy, write the Milton Roy representative listed in your local classified telephone directory. Or, write directly to us.

Manufacturing Engineers

WITH THE EXCLUSIVE STEP-VALVE DESIGN

MILTON Roy COMPANY

1309 EAST MERMAID LANE, PHILADELPHIA 18, PA.

CONTROLLED VOLUME PUMPS AND AUTOMATIC CHEMICAL FEED SYSTEMS

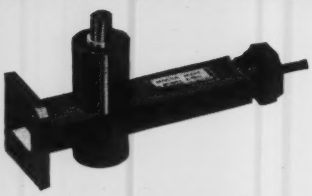
MICROWAVE POWER MEASUREMENTS

COMPLETE COVERAGE! 10 to 12,400 mc!

Instantaneous, direct readings! No adjustment during operation! No tedious computations! Complete new instrumentation for fundamental measurements of CW or pulsed power!

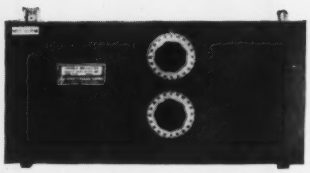
Instrument	Frequencies—Coaxial	Frequencies—Waveguide	Price (f.o.b. Factory)
475B Tunable Bolometer Mount	1,000 to 4,000 mc		$200.00
[illegible] Bolometer Mount	10 to 1,000 mc		$125.00
[illegible] Detector Mount*		2,600 to 3,950 mc	$125.00
[illegible] Detector Mount †		3,950 to 5,850 mc	$95.00
[illegible] Detector Mount †		5,850 to 8,200 mc	$90.00
[illegible] Detector Mount †		7,050 to 10,000 mc	$85.00
[illegible] Detector Mount †		8,200 to 12,400 mc	$75.00
430B Microwave Power Meter	For use at any microwave frequency. Operates with mounts listed above.		$250.00

*For use with bolometer only. †For use with bolometer or crystal.



-hp- 485 Detector Mounts

For rf power measurements in wave guide systems, 2,600 to 12,400 mc (see table) in conjunction with -*hp*- 430A or 430B Power Meter and Sperry 821 barretter. Also may be used to measure relative level, or detect rf energy using a type 1N21 crystal. Semi-tuned by means of a built-in movable short.



-hp- 475B Bolometer Mount

Tunable from 1,000 to 4,000 mc for universal application, greatest convenience in making microwave power measurements. Double-stub design, coupling energy from 50 ohm coaxial systems into 100 or 200 ohm bolometers. Uses Sperry 821 barretter, thermistor or 1/100 ampere instrument fuse.

Get complete information! See your local -hp- representative or write to factory.

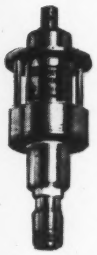
HEWLETT-PACKARD COMPANY

2161 C PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.

New! -hp- 430B Microwave Power Meter—measures pulsed or CW power—.02 to 10 mw

Model 430B gives you *instantaneous* rf power readings *direct* in db or mw at any frequency. (Operates with bolometer mount. Table at left shows -*hp*- mounts now available.) Measures CW power with instrument fuse or barretter as bolometer element; also measures CW or pulsed power using negative temperature coefficient thermistor at 100 or 200 ohm levels. Reads power direct .02 to 10 mw or in dbm from −20 to +10. 5 ranges selected on front panel switch. Accuracy ±5% of full scale. Higher powers may be measured by adding attenuators (-*hp*- Models 370, 380) to rf system. Directional couplers may be used to sample rf energy.

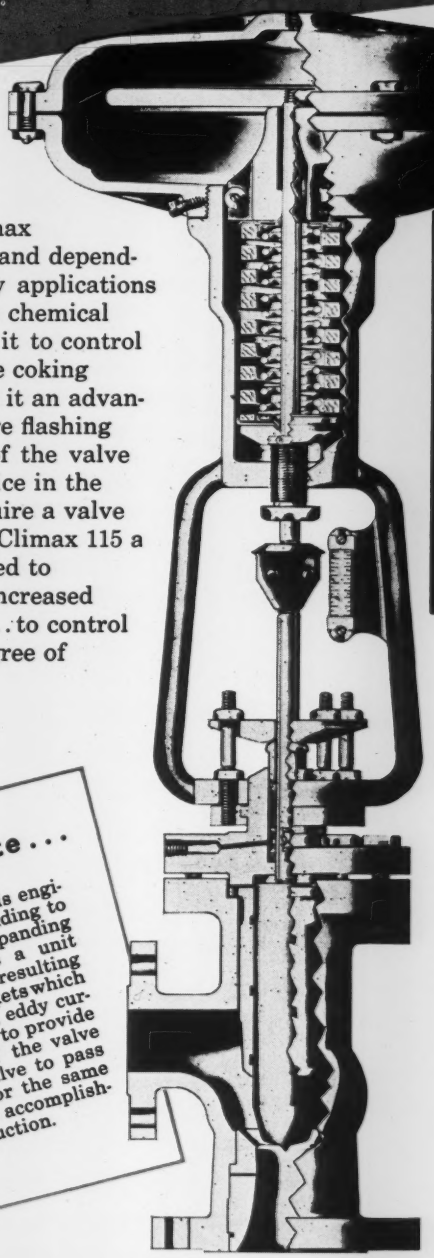
New! -hp- 476A Universal Bolometer Mount



Requires no tuning, no adjustment; measures rf power at any frequency 10 to 1,000 mc. Extremely low VSWR: Less than 1.15, 20 to 500 mc; less than 1.25, 10 to 1,000 mc. Reflected power less than 0.1 db under normal conditions. In combination with -*hp*- 430A or 430B Power Meter gives automatic, instantaneous readings from 0.02 to 10 milliwatts. Measures higher power with addition of attenuators and directional couplers. 50 ohms impedance. Has Type N connector and terminates flexible cables RG8/U, RG10/U, etc.

a NEW BS&B Climax Control

Designed For TOUGH Service in The Process And Power Industries



NOW... a new valve in the Climax family of precision built controls and dependable performers. There are many applications for this angle type valve 115. The chemical and refining industries will want it to control residual oils or liquids which have coking properties. Power plants will find it an advantage for high pressure drops where flashing occurs in the downstream side of the valve piping. Where tough, severe service in the process and power industries require a valve that will "take it", you'll find the Climax 115 a valve that will "do it". It's designed to control gases requiring greatly increased volume upon release of pressure... to control liquids that are subjected to a degree of flashing that would render an expanded outlet necessary.

For minimum turbulence...

The valve body of the Climax 115 is engineered with a sweep flow inlet leading to a venturi throated valve seat expanding into the outlet...all designed as a unit for minimum turbulence. The resulting streamlined flow eliminates pockets which are the cause of flow reversal, eddy currents and erosion. It also tends to provide a maximum port efficiency of the valve which, in turn, allows the valve to pass greater quantities of fluid for the same diameter port than would be accomplished in a globe type of construction.

BS&B Climax Type 115*

Expanded Outlet Diaphragm Control Valve

***115-D— Air to close valve...opens with air supply failure**

115-DRT—Air to open valve...closes with air supply failure

The diaphragm motor mechanism in the Type 115 Climax is the same used in all Climax Type 86 Control Valves, selected for the particular service required. Pressure balanced top works can also be supplied. Type 115 is furnished with carbon steel angle type bodies in expanded outlet sizes—2″ x 3″ ...3″ x 4″...and 4″ x 6″ with standard 150#, 300#, and 600# ASA flanges.

CLIMAX BS&B CONTROLS

BLACK, SIVALLS & BRYSON, INC.

CLIMAX CONTROLS DIVISION, DEPT. 4-V6

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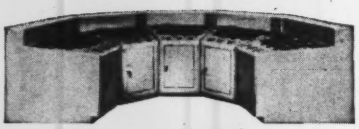
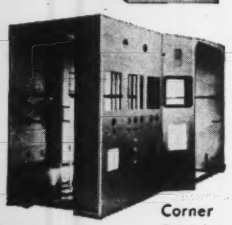
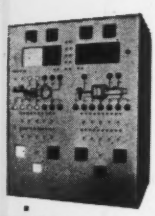


Benchboard Console



Five Section Cubicle Control Board and Lighting Canopy

Corner Cubicle Section



Refinery Cubicle with Mimic Flow Diagram in Color

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Instruments

THE MAGAZINE OF MEASUREMENT INSPECTION · TESTING · CONTROL

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LEWIS HERMETICALLY SEALED TEMPERATURE INDICATORS FOR AIRCRAFT

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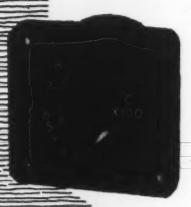

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Multi-function indicators with identification plates for cylinder-head or bearing temperatures. Range, minus 50 to 300°C, for use with iron-constantan thermocouples.

The 2" indicators are designed for ring-clamp mounting or may be furnished with type A-1 removable bezel if specified . . .

Special ranges to order . . .

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RESISTANCE THERMOMETERS

Single indicators with 2" standard case for ring clamp mounting or may be furnished with type A-1 removable bezel if specified . . .

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Heating-duct indicators, range minus 20 to plus 300°C . . . cylinder-head indicators, range minus 50 to plus 300°C for use with AN-B-31 bulb . . .

Special ranges to order . . . illustrated is oil temp gauge, range zero to plus 190°C . . .
All resistance thermometers operate on 28 volts DC.

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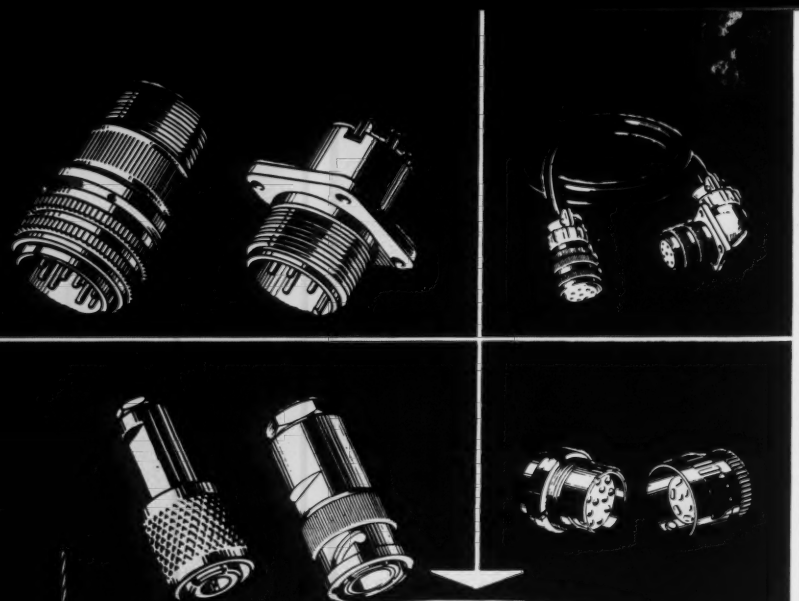
Manufacturers of *Complete* Temperature Measuring Systems for Aircraft

NAUGATUCK, CONNECTICUT



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COVER STORY

The panels of pneumatically-operated U-tube gages pictured on this month's cover indicate the amount of oil in the 10,000-barrel field tanks at the Grease & Compounding Department of the Socony-Vacuum Oil Company, Trenton, Michigan. The height of the mercury column in the gage exactly balances the head of oil in the tank. Scales on these gages are graduated in pounds; thus no correction is required for changes in temperature. Conversion to gallons, when required, gives the correct gallonage at 60 deg. F., regardless of the temperature of the oil, without any further correction. The gaging system was designed and installed by King Engineering Corporation, Ann Arbor, Michigan.

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Specifications

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X-axis: Deflection factor: Amplifier at full gain, 0.30 p-p (0.1 rms) v/in.; direct, 80 p-p (26 rms) v/in. ±20%. **Frequency response:** uniform within 10% to 100 kc., within 50% to 300 kc. **Input impedance:** to amplifier, 2 meg., 50 μμf; direct (balanced), 4 meg., 20 μμf; (unbalanced) 2 meg., 20 μμf.

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for Oscillography

Instrument Division, Allen B. Du Mont Laboratories, Inc., 1500 Main Ave., Clifton, N. J.

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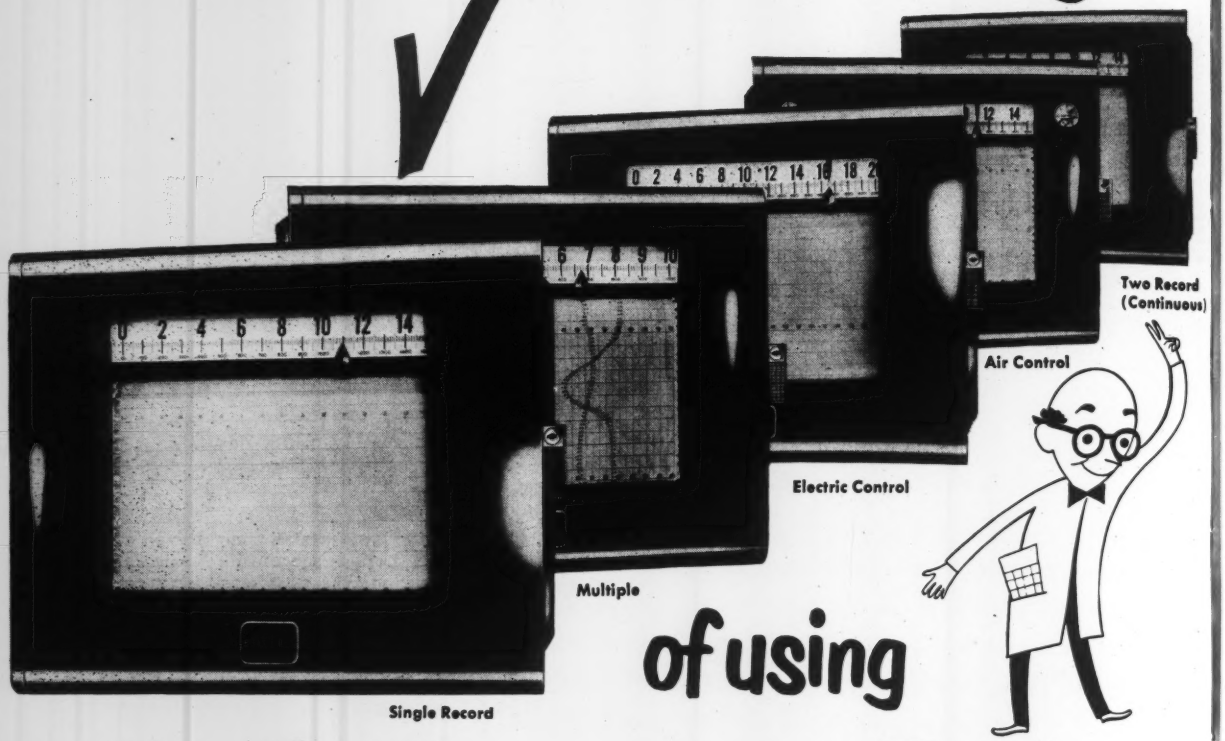

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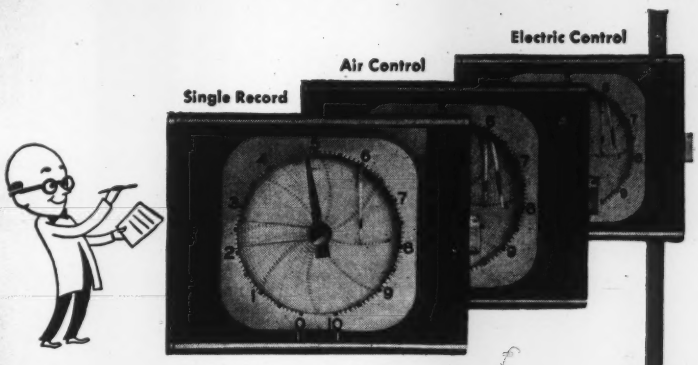

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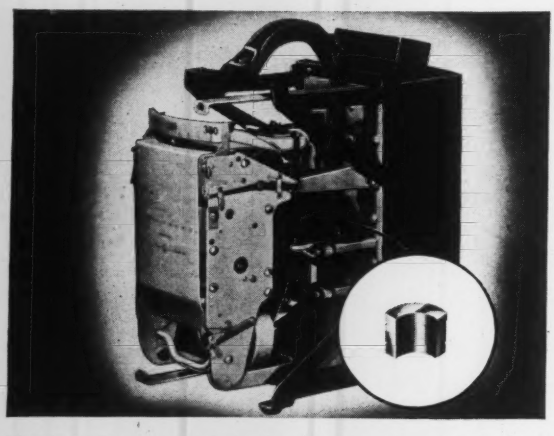
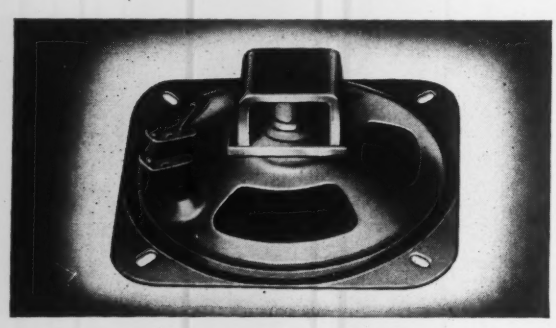
These 4 cases show how lasting energy without wires breaks down design barriers, opens the door to finer product performance, big new profit opportunities



METERS—Here, a Carboloy concentric magnet element is the measuring mechanism of this new-type portable current recorder. The permanent magnet cut down fabrication costs by eliminating other power-supplying parts. It also reduced the recorder's weight by 10 pounds and greatly contributed to the sensitivity and accuracy of the instrument. A typical case of modernization through magnets.



SPEAKERS—Many radio and TV speakers now use Carboloy permanent magnets to replace other electrical fixtures in the voice coil. Current passing through this uniform magnetic field causes the voice coil and attached cone to vibrate in proportion to the applied voltage . . . producing truer tone. These Carboloy magnets will never fail, never need maintenance. Permanent magnets are also used in television focusing assemblies.

Is magnetic energy essential or useful in your product?

Then the chances are excellent that Carboloy permanent magnets can improve its function, lower its cost . . . put you out front of your competitors with a finer-performing, more dependable product.

Here's why: Carboloy permanent magnets are simple, self-containing sources of magnetic energy that *never fail*. They need no outside power. They help simplify design and reduce fabrication costs by eliminating wires, coils and other operating parts.

Because they are very powerful, even in small sizes, they let you build a lighter, more compact product, too (particularly important in magnetos, motors, instruments, control devices, communications equipment and other items for the aircraft industry).

Thousands of applications

The Carboloy magnet applications on these pages are but 4 of thousands. Perhaps they'll spark an idea for a similar application in your radio or TV set, thermostat, voltmeter or whatever electrical product you build.

Check them. Then check Carboloy magnet engineers . . . the most skillful in the business. They'll give you a hand in magnet design and application at no cost to you. *And Carboloy production lines can supply you with the finest, most uniform magnets that money can buy.* Any size, any shape. Cast or sintered.

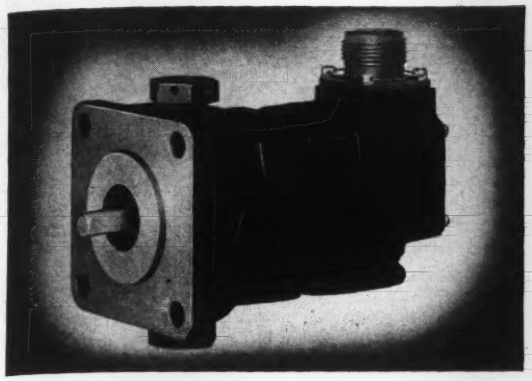
For more information, send coupon for free copies of the Carboloy Magnet Design Manual and Standard Stock Catalog.

CARBOLOY

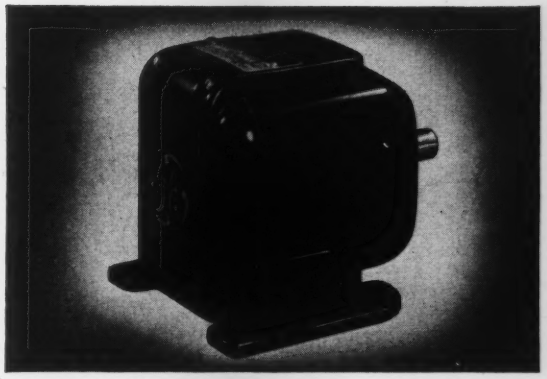
DEPARTMENT OF GENERAL ELECTRIC COMPANY

11155 E. 8 Mile Ave., Detroit 32, Michigan

improve your electrical products?



GENERATORS—When plane engineers left only a 6" x 6" space for a jet's tachometer generator, the design problem was whipped with a Carboloy permanent magnet. One tiny magnet supplied the strong magnetic field required. It eliminated coils and wires previously used, thereby saving space and permitting a compact generator design that fit the limited area.



CONTROLS—A new plugging control for brakeless stopping of polyphase induction motors features a Carboloy permanent magnet. An eddy current disk, rotating in the magnetic assembly, creates a torque. As the motor's speed nears zero with the power reversed, the torque decrease interrupts the circuit and quickly stops the motor.

Which of these outstanding advantages of Carboloy permanent magnets can help you improve your product?

1 **SIMPLE**—Compact, self-containing sources of energy with no operating parts.

2 **UNIFORMLY POWERFUL**—Guaranteed to meet or surpass the standard external energy minimum.

3 **LAST FOREVER**—Will supply a constant, uniform magnetic field indefinitely.

4 **NO WIRING**—Eliminate need for coils, windings, or other electrical fixtures.

5 **COOL-RUNNING**—Won't generate heat; need no provisions for heat dissipation.

6 **NO OPERATING COSTS**—Operate without maintenance costs or any power supply.

7 **NO POWER FAILURES**—There is no outside source of power to fail!

8 **COMBINE ELECTRICAL AND MECHANICAL FEATURES**—Transform electrical energy into mechanical motion; mechanical motion into electrical energy.

9 **SIMPLIFY MECHANICAL ASSEMBLIES**—Exert strong tractive force for holding, lifting and separating devices, which eliminates component parts, makes product design and fabrication extremely simple.

10 **UNINTERRUPTED OPERATION**—Magnetic energy flows *continually* and *forever!*

11 **MOISTURE-RESISTANT**—No coils to collect moisture.

12 **CREATE SAVINGS**—Reduce weight, save space, lower cost of fabricating and eliminate other, often more costly, power-supplying parts.

"Carboloy" is the trademark for the products of Carboloy Department of General Electric Company

ALNICO PERMANENT MAGNETS

—MAIL THIS COUPON TODAY—

CARBOLOY Department of General Electric Company
11155 East 8 Mile Ave., Detroit 32, Michigan

Gentlemen:
Please rush me, without cost or obligation, copies of your latest Carboloy Permanent Magnet Design Manual and your Permanent Magnet Standard Stock Catalog.

NAME_____ POSITION_____

COMPANY NAME_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

Simplicity

NEW simplified Recording Potentiometer by WESTON

built to the same high standards of accuracy . . . sensitivity . . . durability as all instruments bearing this name.

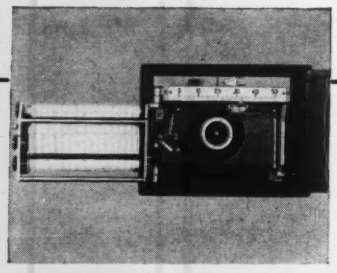


Chart frame swings out full 180° on straight pivots, chart remaining in time sequence. Charts easily installed in matter of seconds.

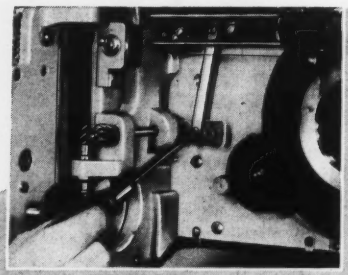
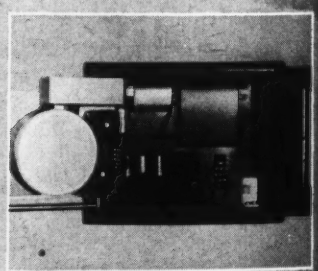


Chart speeds changed by simple screwdriver adjustment. Ranges quickly changed, too, by simply inserting correct range standard.

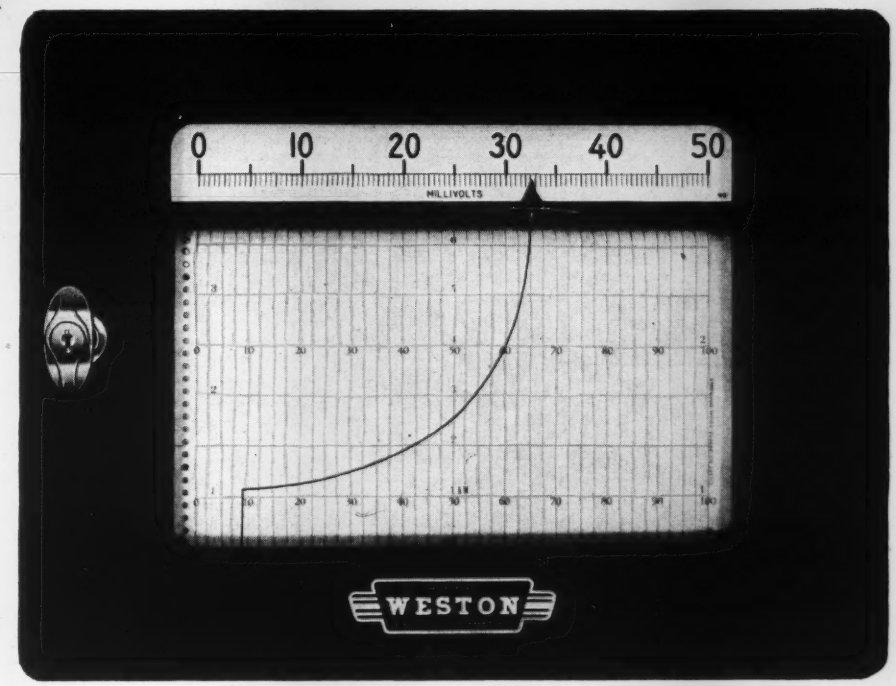


Note extreme simplicity both mechanical and electrical; as well as complete accessibility for quick maintenance and servicing.

WESTON TAG 9128

WESTON *Instruments*

INDICATE . . . RECORD . . . CONTROL



With this new high-speed Recording Potentiometer WESTON sets a new pattern for sound, simplified design . . . for simplicity and economy of maintenance . . . and for sustained high accuracy and sensitivity. With fewer components . . . with all assemblies greatly simplified and quickly interchangeable . . . with all adjustments including range changes made quickly on-the-line . . . with new compactness, ruggedness, and sustained high accuracy . . . this modern instrument will cut costs, and eliminate headaches wherever instrumentation is involved. You will want all the facts. Ask your local WESTON Representative, or write direct . . . WESTON Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey . . . *manufacturers of Weston and Tag Instruments.*

Chart installation is Simpler — with new accessibility, and no loose parts to handle, chart can be installed in half the usual time. The chart drive has been simplified, made more positive, too.

Chart speed changes are Simpler — exclusive multi-speed chart drive permits instant selection of five different speeds with ordinary screwdriver. Speeds doubled or quadrupled by two simple gear changes.

Changing ranges is Simpler — you just insert correct range standard and tighten with screwdriver. Reference junction compensation changed in like manner. *No soldered connections used.* Universal slide wire needs no changing.

Pen and carriage are Simpler — pen quickly, easily filled without removal, or taking instrument out of service. Pen won't clog, never pumps or syphons-off, needs no priming after initial starting. One-piece pen carriage has oil-less bearings and is driven by woven stainless steel cable.

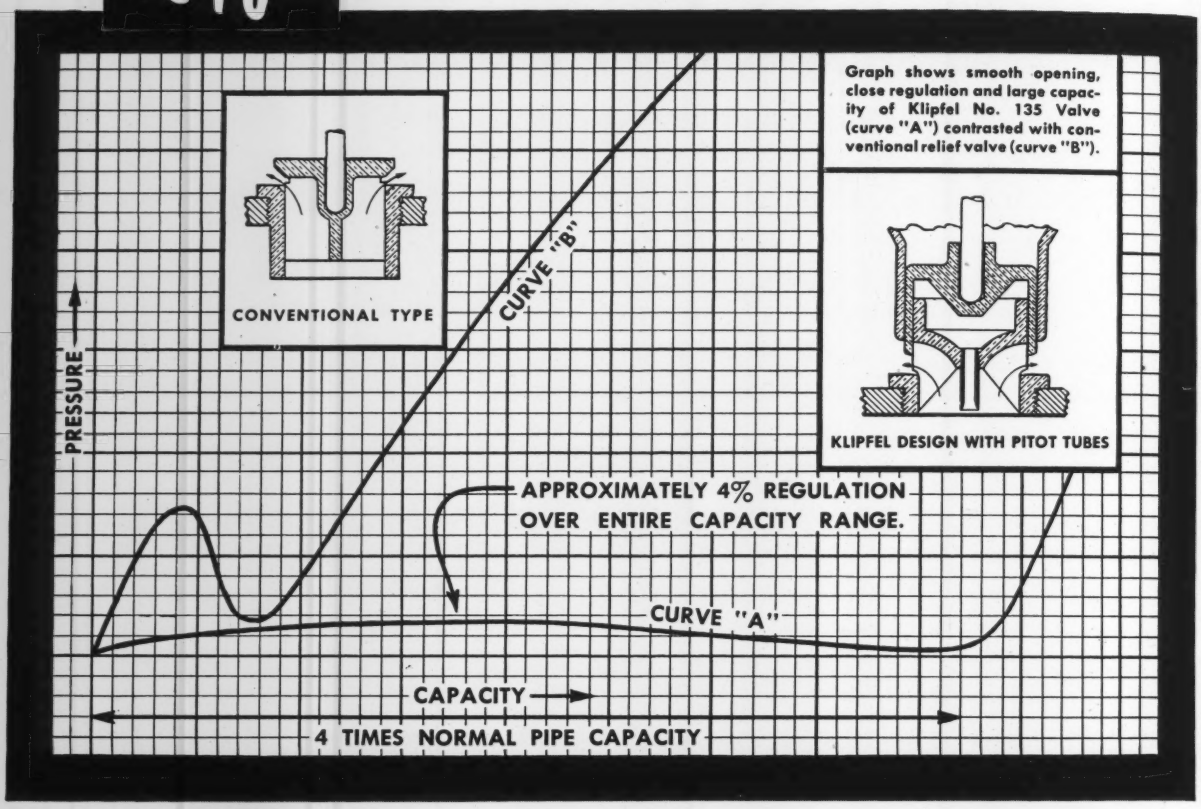
New Simplified ruggedness — all parts amply proportioned for strength and rigidity, to maintain mechanical alignment under tough usage.

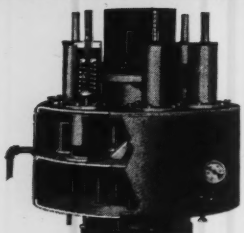
All maintenance is Simpler — plug-in type amplifier, for example, removed in a jiffy. Liberal use of oil-less bearings reduces lubrication problems. No on-the-job soldering required.

Using relief valves?

CHECK THE PERFORMANCE

OF Klipfel NO. 135 SINGLE and MULTIPORT VALVES


Graph shows smooth opening, close regulation and large capacity of Klipfel No. 135 Valve (curve "A") contrasted with conventional relief valve (curve "B").
CONVENTIONAL TYPE
CURVE "B"
KLIPFEL DESIGN WITH PITOT TUBES
PRESSURE
APPROXIMATELY 4% REGULATION OVER ENTIRE CAPACITY RANGE.
CURVE "A"
CAPACITY
4 TIMES NORMAL PIPE CAPACITY



PERFORMANCE CHARACTERISTICS

Compensated Spring Loading—
by using fluid velocity.

Tight Closing—
with thin edged seat for low venturi effect.

Chatter-proof Operation—
though inherent dash-pot construction.

Multiport Valves—
open in sequence minimizing wire drawing and improving regulation. Positive testing of each valve with external handle.

Single or multiport, the Klipfel No. 135 maintains steam back pressure accurately. Among the features which have made it a favorite with operating and maintenance men are:

INNER VALVE—*an inverted cup slides smoothly on a piston which is integral with the threaded seat bushing.*

EXTERNAL SLEEVE—*an extra feature—permits close regulation with variable outlet pressure by venting spring chamber to a constant pressure source.*

SPRING—*extra long with low spring scale.*

BODY—*in single port, bronze, semi-steel or steel casting. In multiport, all-welded steel plate body.*

PRESSURE RANGE—*single port, up to 300 P.S.I.G.; multiport, vacuum to 20 P.S.I.G.*

FOR FULL DATA on the Klipfel No. 135, write Dept. DA-5.

Klipfel VALVES INC.
HAMILTON, OHIO

For *Critical* Applications

Triplett 630-A Has No Counterpart

Accuracy
to 1½%

Readability
with a Mirror-Scale

Adaptability
with ½% resistors

Try it at your distributor's

Triplett
TRIPLETT

TRIPLETT ELECTRICAL INSTRUMENT CO., BLUFFTON— OHIO

FISCHER & PORTER

P-4

PNEUMATROL

Flexible, die-cast building-block construction—six modes of control; right or left or dual case mounting, or point-of-measurement mounting.

High capacity (1.8 SCFM), non-bleed relay valve.

Double slack diaphragm design eliminates dead space and critical relay adjustment.

Large integral air passages permit maximum response, eliminate piping.

Accessible capillary restriction and integral filter.

Differential input assembly is an integral part of controller, assuring tracking.

Rugged, self-aligning "Barrel-Bearings"—eliminate friction.

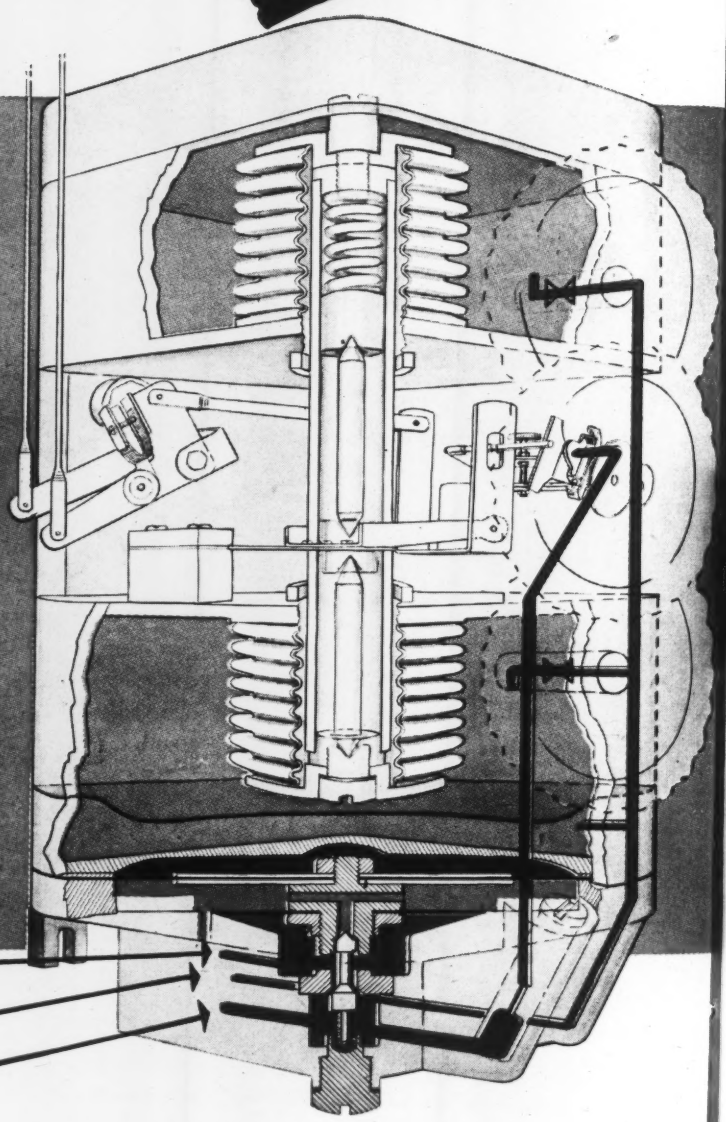
Jewel-mounted stainless steel flapper, rotatable around fixed stainless steel nozzle for proportional band adjustment and reversal of action.

Self-aligning, rigidly-coupled bellows assembly.

Beryllium-copper flexure spring, pivot-pin coupled to bellows without backlash or side thrust.

Long-path adjustable resistor valves for reset and derivative, O-ring sealed, non-jamming, calibrated 0.02—5 min. or 0.2—50 min.

Independent derivative vibration stabilizer; pneumatic balance action.

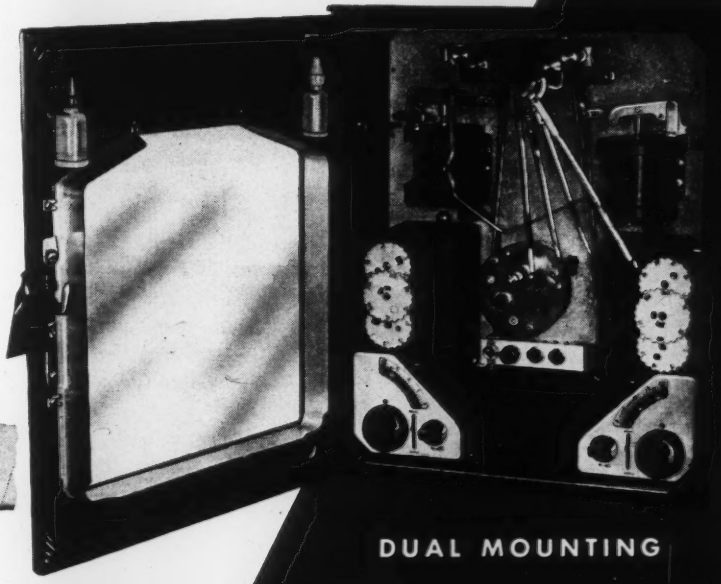


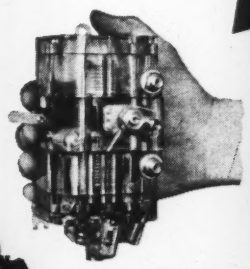
Pneumatic Controller

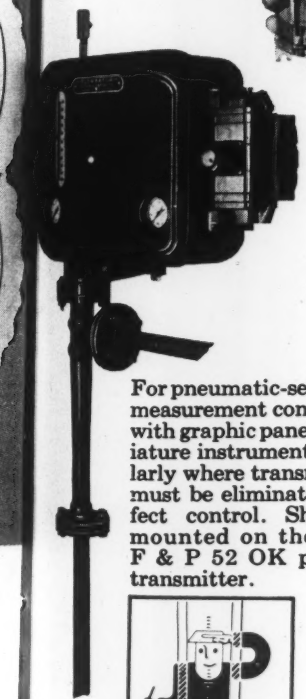
for either instrument or point-of-measurement mounting

for
- rate of flow
- pressure
- differential pressure
- temperature
- liquid level
- viscosity

The P-4 Pneumatrol is the *first* controller suitable for point-of-measurement installation as well as either single or dual case mounting. Knowing more about the many uses of the P-4 may lead to closer control of your processing operations. Get all the data NOW. The convenient coupon will bring you full information by return mail. Send for it while the subject is fresh in your mind.







The P-4 incorporates both proportional and derivative actions with automatic reset response for precise positioning... in stacked units, as shown in this transparent model.

DUAL MOUNTING

- Complete mounting of transfer switch and regulator within the case.
- Greater panel space economy.
- New die-cast aluminum case and door.
- All accessories visible through door.
- External knobs for instant manual operation.
- *Everything* is inside the case, eliminates external manual panels.

For pneumatic-set, point-of-measurement control for use with graphic panels and miniature instruments, particularly where transmission lag must be eliminated for perfect control. Shown here mounted on the popular F & P 52 OK pneumatic transmitter.

FLOWRATOR

FISCHER & PORTER COMPANY

1360 COUNTY LINE ROAD, HATBORO, PENNA.

Please send me by return mail complete specifications on your new P-4 Pneumatrol.

NAME_____

POSITION_____

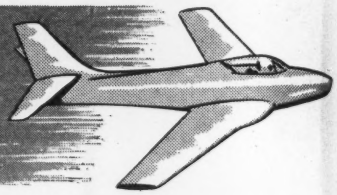
COMPANY_____

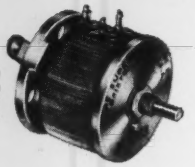
ADDRESS_____

CITY & STATE_____

A COMPLETE

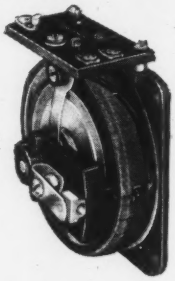
STANDARD LINE



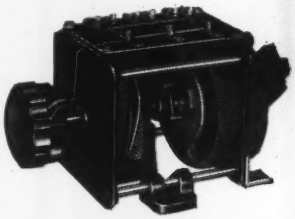


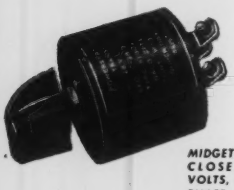
MIDGET FRAME SIZE—OPEN TYPE FOR 28 VOLT, 400 CYCLES, SINGLE PHASE DUTY; 0-28 VOLTS, 4 AMPS. OUTPUT

1 KVA FRAME SIZE—OPEN TYPE FOR 115 VOLTS, 400/800 CYCLES, SINGLE PHASE SERVICE; 0-115 VOLTS, 3.0 AMPS. OUTPUT



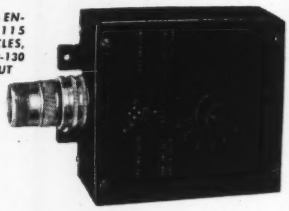
1 KVA FRAME SIZE—OPEN TYPE FOR 230 VOLTS, 400/800 CYCLES, THREE PHASE DUTY; 0-230 VOLTS, 3.0 AMPS. OUTPUT



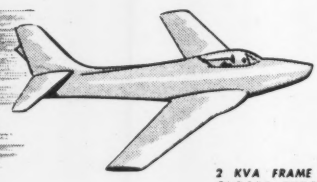


MIDGET FRAME SIZE—ENCLOSED TYPE FOR 120 VOLTS, 400 CYCLES, SINGLE PHASE DUTY; 0-120 VOLTS, 1.0 AMPS. OUTPUT

1 KVA FRAME SIZE—ENCLOSED TYPE FOR 115 VOLTS, 380/1600 CYCLES, SINGLE PHASE INPUT; 0-130 VOLTS, 4.0 AMPS. OUTPUT

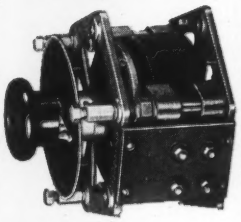


POWERSTAT



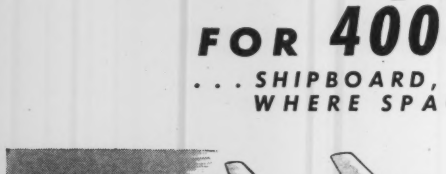
Variable Transformers

2 KVA FRAME SIZE—ENCLOSED TYPE FOR 115 VOLTS, 400/800 CYCLES, SINGLE PHASE INPUT, 0-130 VOLTS, 15 AMPS. OUTPUT



FOR 400-800 CYCLE OPERATION

. . . SHIPBOARD, AIRBORNE, GROUND, MOBILE EQUIPMENT WHERE SPACE AND WEIGHT SAVINGS ARE VITAL



THREE BASIC FRAME SIZES

MIDGET	1 KVA	2 KVA
ENCLOSED AND OPEN CONSTRUCTION IN RATINGS UP TO 1/2 KVA	ENCLOSED AND OPEN CONSTRUCTION IN RATINGS UP TO 1-1/2 KVA	ENCLOSED AND OPEN CONSTRUCTION IN RATINGS UP TO 2-1/2 KVA

Weight and space must be conserved in shipboard, airborne and allied equipment for national defense needs. By operating electrical apparatus at 400 cycles and higher frequencies, this is accomplished. Since variable transformers are a necessary component in much of this equipment, a complete standard line of POWERSTAT variable transformers is now available. A wide range of types is offered to meet BU Air, BU Ships, Air Corps and Signal Corps specifications. Standard types are built to fulfill the demands of adverse operating conditions including excessive shock, vibration, bounce; high humidity; low and high ambient temperatures.

Standard types are described in Bulletin P552H. Send for your copy today. If a standard assembly does not meet your exacting requirements, our engineering department will work with you to build a POWERSTAT to your specifications.

WRITE TO:
706 THURE AVENUE,
BRISTOL, CONNECTICUT

THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT

• STABILINE AUTOMATIC VOLTAGE REGULATORS • POWERSTAT VARIABLE TRANSFORMERS • VARICELL D-C POWER SUPPLIES • VOLTBOX A-C POWER SUPPLIES • SUPERIOR 5-WAY BINDING POSTS • POWERSTAT LIGHT DIMMING EQUIPMENT

SK ENGINEERING News

Rotameters Offer Definite Advantages In Metering Fluid Rate of Flow

(On-The-Job Photos by Courtesy of Hoffmann-LaRoche, Inc., Nutley, N. J., Manufacturers of Pharmaceutical Chemicals and Vitamins)

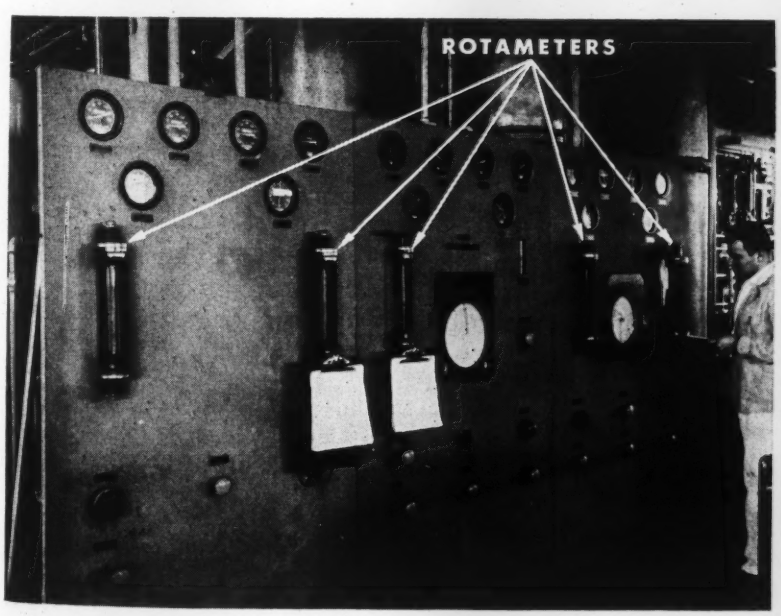
In the modern plant of Hoffmann-LaRoche, Inc., in Nutley, N. J., SK Universal Rotameters are used in large numbers to measure fluid flow rates in the manufacture of pharmaceutical chemicals and vitamins.

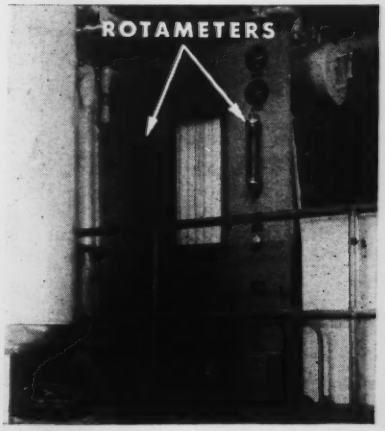
In metering rate of flow, Rotameters offer definite advantages. They are fast and accurate—are easy to read. Since they have only one moving part, the rotor, maintenance is very simple. Cleaning is easy and fast since the Rotameter can be dis-assembled without disturbing pipe connections. They are versatile in that they can be designed to meet varying requirements.

The SK Universal Rotameter is suitable for most applications, however, many other types are available. These other types include: Chemical, Armored, Flow Alarm, Electronic Recording, Pneumatic Recording, Laboratory, Bypass, and other Rotameters. Each type offers definite construction and operation features of value to anyone desiring to measure fluid rate of flow.

All types are based upon the same basic principles of operation. Fluid enters the tapered meter tube at the bottom and leaves at the top. The fluid exerts a force on the rotor which is proportional to the rate of flow and holds the rotor in a steady position in the tube for any rate of flow within the range of the meter. The rotor position in regard to the scale on the meter tube indicates the rate of flow.

Bulletin 18-RA pictures and briefly describes all types of SK Rotameters and lists, by number, the detailed bulletin relating to each. Request a copy.





The SK ENGINEERING NEWS, published quarterly in magazine form, contains articles on principles and applications of equipment manufactured by Schutte and Koerting Company. We will gladly add your name to the NEW'S mailing list.

INTERNATIONAL RECTIFIER CORPORATION

Selenium Photo-Cells

A-2M –
Window: 9/32" diameter. 13 microamperes at 100 foot-candles illumination. Enclosed in a phenolic case with threaded terminals. This unit is not designed for immersion.

DP-2 –
Hermetically sealed. Window: 15/32" x 3/16". 25 microamperes at 100 foot-candles illumination. Terminals fit standard crystal mounting base. Supplied with corrosion-resistant finish.

DP-5 –
Hermetically sealed. Window: 1½" x 1½". 600 microamperes at 100 foot-candles illumination. Corrosion-resistant finish. Threaded terminals.

DP-3 –
Hermetically sealed. Window: 9/16" x 3/8". 50 microamperes at 100 foot-candles illumination. Terminals fit standard crystal mounting base. Supplied with corrosion-resistant finish.

INTERNATIONAL hermetically sealed Photo-cells (DP-2, DP-3, DP-5) are designed for immersion and eliminate the expense of transparent tubing in many applications where light is used to serve as a quality control in manufacturing processes.

STANDARD UNMOUNTED PHOTO-ELECTRIC CELLS

A 15
2" diam.
750 microamperes*

A 10
1¾" diam.
500 microamperes*

A 5
1⅛" diam.
250 microamperes*

B 10
1-11/16" x 7/8"
340 microamperes*

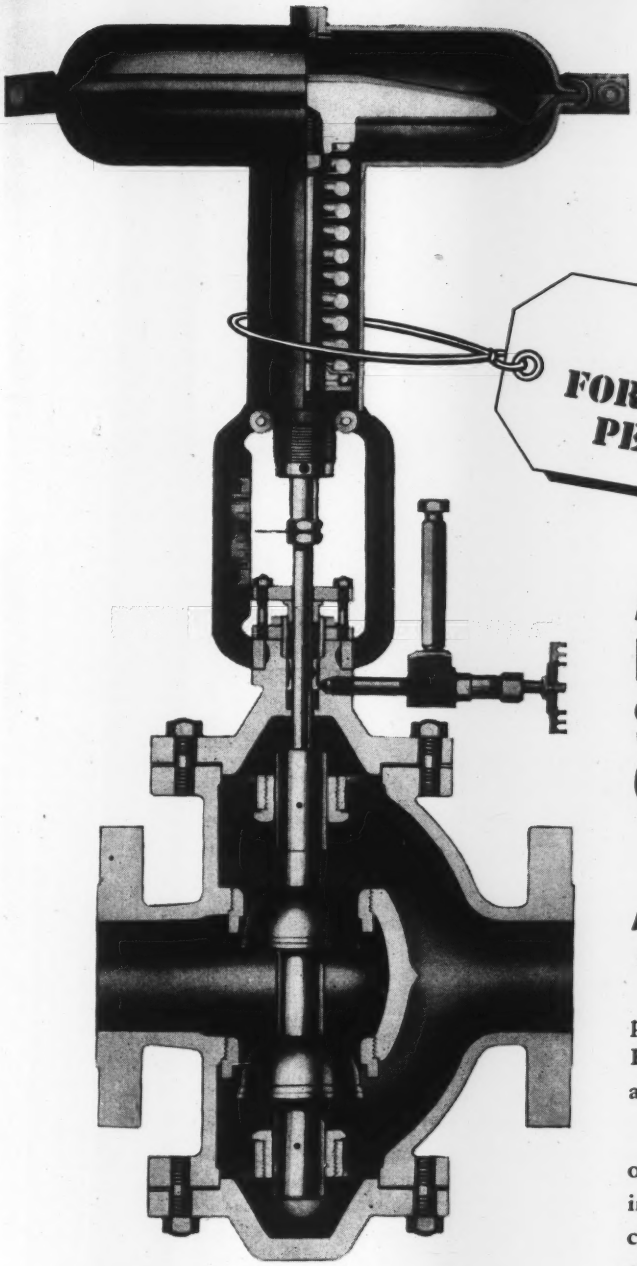
B 5
1-7/16" x 41/64"
220 microamperes*

B 2
23/32" x 7/16"
75 microamperes*

** At 100 foot-candles illumination and 100 ohms external resistance.*

INTERNATIONAL RECTIFIER
CORPORATION

General Offices: 1521 E. Grand Ave., El Segundo, Calif. · Phone: El Segundo 1890
Chicago Branch Office: 205 West Wacker Drive · Phone: Franklin 2-3889



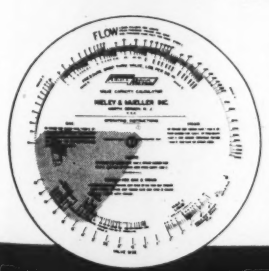
AMERICA'S LEADING INDUSTRIES PUT THE STAMP OF APPROVAL ON KIELEY & MUELLER CONTROL VALVES

Make It Your Business to Find Out Why!

All over the country leading companies in the process industries are solving tough problems with K & M control valves, designed especially for precise and positive control by instrumentation.

More and more, as the outstanding performance of these superbly engineered valves becomes known, important companies with pressure and flow applications are turning to K & M for the skill, knowledge and experience that assure reliable automatic control of pressures, temperatures, rates of flow and liquid levels.

There is a qualified K & M representative near you, eager to discuss your control problems and able to provide the most satisfactory solution.

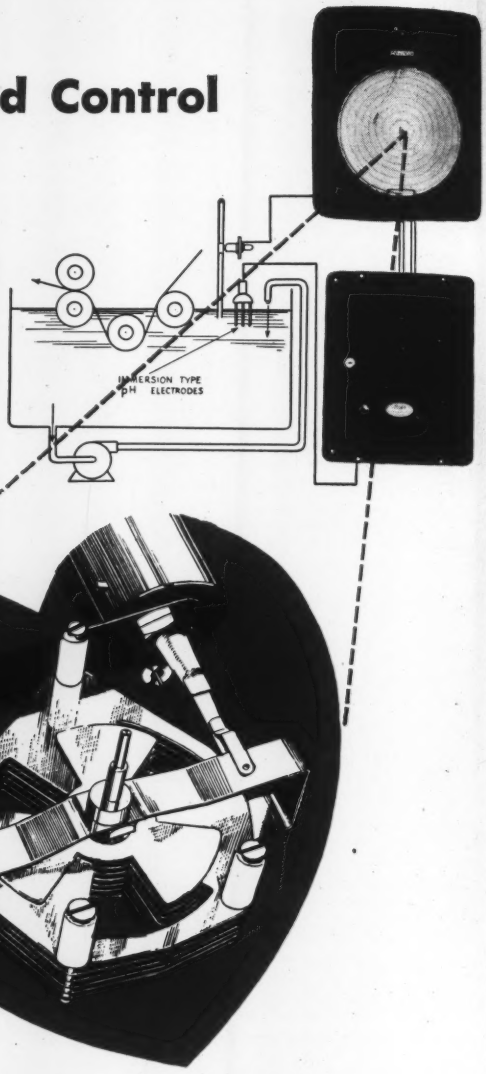


This extremely accurate circular slide-rule type K & M valve capacity calulator includes correction scales for steam quality, liquid and gas specific gravity and a flowing temperature scale for gases. Sent without charge in response to a request on your business stationery.

K&M

Accurate pH Measurement and Control

IT'S "DUCK SOUP" FOR DYNALOGS*



In many chemical operations, accurate control of pH is essential to maximum yield and purity of product since it governs reaction velocities and suppresses undesirable side reactions in the processing.

Here's why Dynalogs are ideal for Measuring or Controlling pH

The heart of Dynalog Instruments, shown at the right, eliminates the conventional slidewire and provides an unequalled combination of speed, sensitivity and accuracy. This *stepless* as well as continuous balancing mechanism responds quickly and positively to the smallest change in pH values.

Whatever your requirements for accurate pH measurement or control, there's a Foxboro Dynalog Instrument designed to meet them . . . indicating, recording or controlling. Write for Bulletin 430. **The Foxboro Company, 466 Neponset Avenue, Foxboro, Mass., U. S. A.**

* Reg. U.S. Pat. Off.

ADVANCED ENGINEERING THROUGHOUT

Designed to take full advantage of electronic circuits, Dynalog Instruments are virtually free from the mechanisms used in conventional bridge-type instruments. They have no slidewire, no moving contacts, no high-speed motor, no gears, no galvanometer, no batteries to standardize. They require essentially no maintenance except occasional replacement of standard radio tubes. Pneumatic Dynalog Controllers are available where automatic operation is desired.

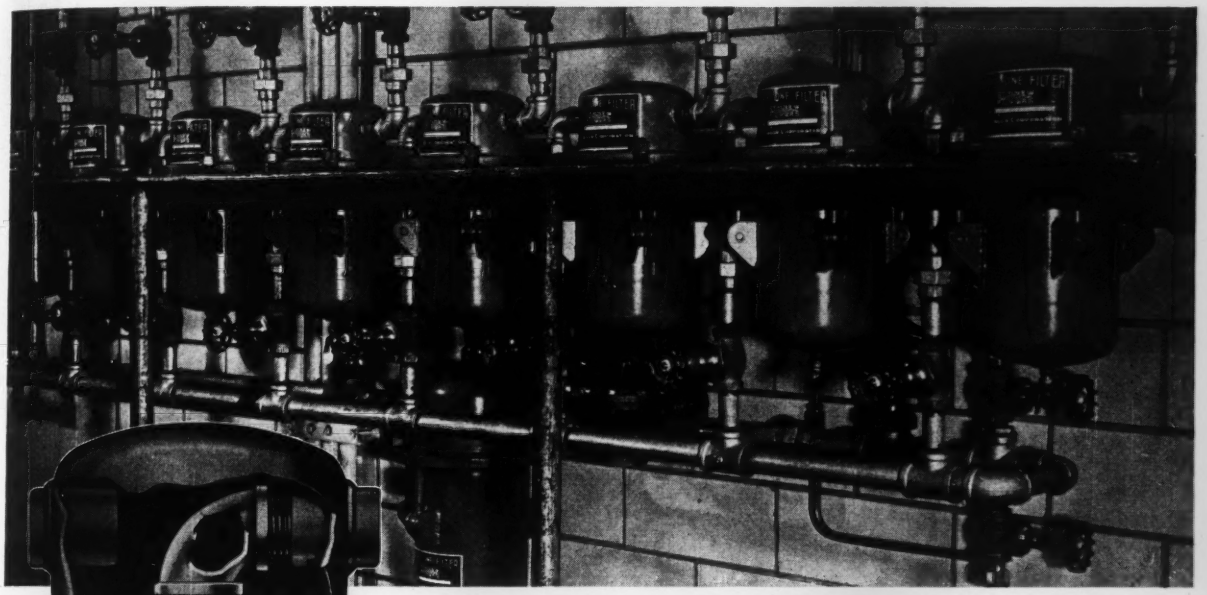
Beckman Glass Electrodes are the primary elements of Dynalog pH Instruments. They are suitable for use in nearly all types of solutions regardless of color, viscosity, rate of flow, suspended solids and oxidizing or reducing agents.

FOXBORO
Reg. U.S. Pat. Off:

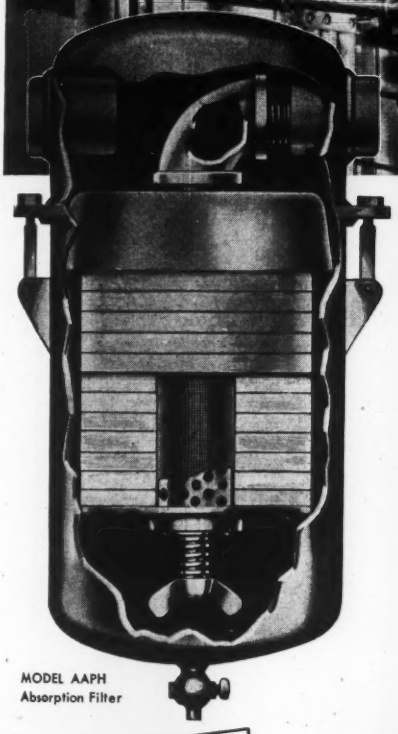
DYNALOG ELECTRONIC INSTRUMENTS

THESE STAYNEW ABSORPTION FILTERS

Protect Automatic Combustion Controls from All Oil, Moisture, Solids



Specially developed Staynew Filters guarantee clean, dry air for Boiler Controls at Rochester Gas & Electric Corp.



MODEL AAPH
Absorption Filter

The Rochester Gas & Electric's new automatic boiler controls needed *clean* air for efficient operation—air that's free of oil and moisture as well as solids. In order to accomplish this, coke and then charcoal filters were tried. An accumulation of oil continued to "gum up" the reducing valve feeding the master control. Our engineers were called in, and after thorough study, a special felt pad filter (shown at left) was developed and the new filters were installed. *Result*—no fouling has occurred in the control air system since the filters were installed in 1949.

If you have a special filtration problem call on Dollinger's experienced engineers. Write today for Bulletin B-1A.

Representatives in Principal Cities

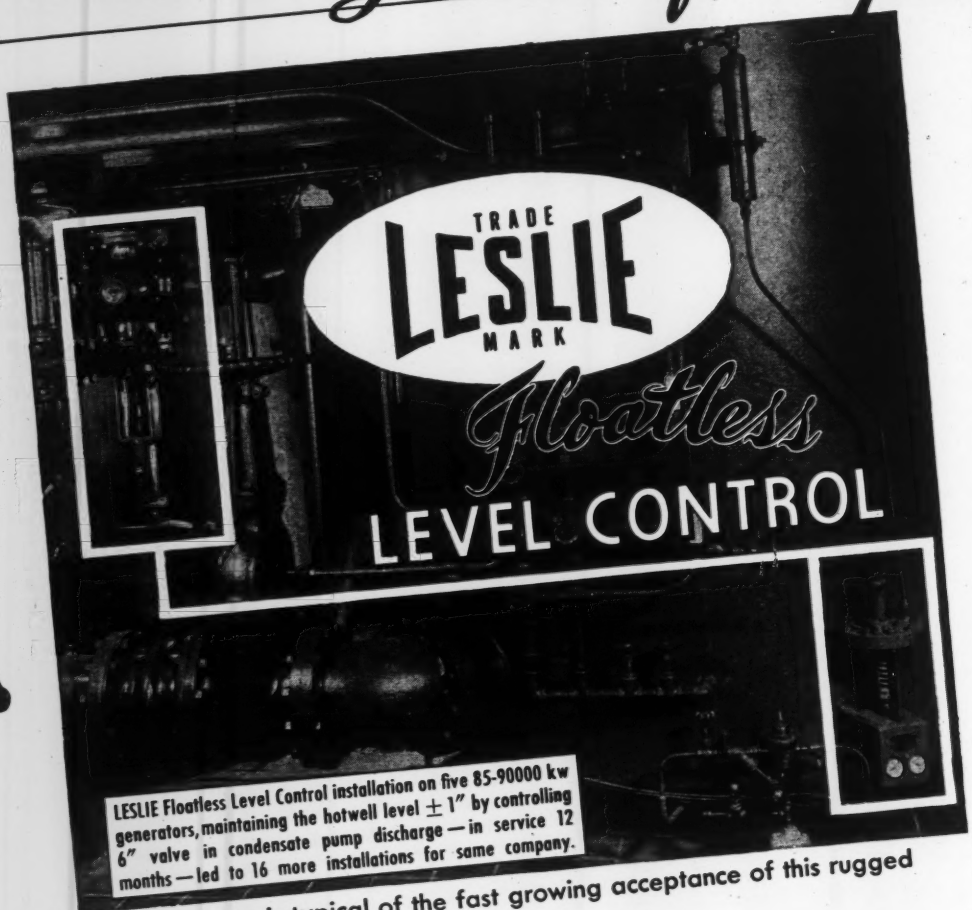
DOLLINGER PROTECTOMOTOR STAYNEW FILTERS

DOLLINGER CORPORATION

63 Centre Pk., Rochester 3, N. Y.

ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

An Outstanding Record of Acceptance!



LESLIE Floatless Level Control installation on five 85-90000 kw generators, maintaining the hotwell level ± 1" by controlling 6" valve in condensate pump discharge — in service 12 months — led to 16 more installations for same company.

The above is typical of the fast growing acceptance of this rugged and accurate level control.

ADVANTAGES

- EASY TO INSTALL
- ACCURATE REGULATION (± 1" Water Column)
- NO FLOATS, STUFFING BOXES, ETC.
- MULTI-MEDIUM ACTUATED
- DIAPHRAGM PRESSURE ELEMENT
- ACTION REVERSIBLE

Applications: On open and pressurized vessels, including boilers, tanks, evaporators, heaters, standpipes, etc.

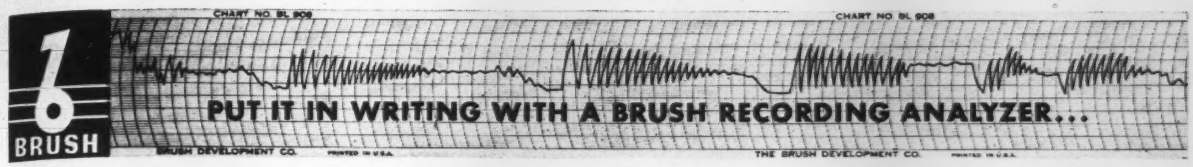
PRINTED IN U.S.A.

***SEND* for illustrated Bulletin**

Look for LESLIE Regulators under "Valves" or "Regulators" in your Classified Telephone Directory in leading industrial cities where LESLIE factory-trained engineers are located.

LESLIE CO., 299 Grant Avenue, Lyndhurst, New Jersey 1627

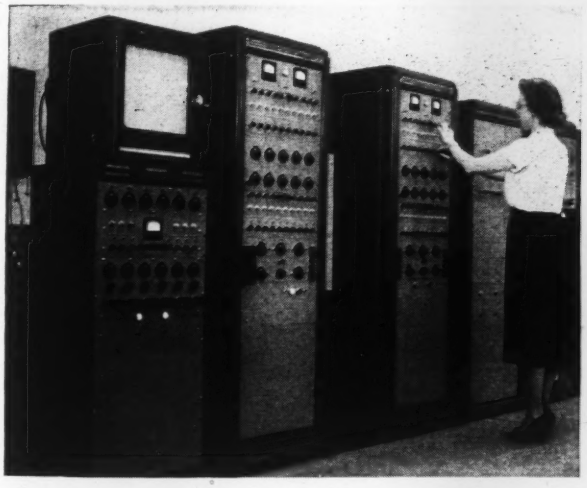
PRESSURE REDUCING VALVES • PRESSURE CONTROLLERS • FLOATLESS LEVEL CONTROLS
PUMP GOVERNORS • TEMPERATURE REGULATORS
SELF CLEANING STRAINERS • AIR HORNS • STEAM WHISTLES


BRUSH
CHART NO. BL 908
CHART NO. BL 908
PUT IT IN WRITING WITH A BRUSH RECORDING ANALYZER...
BRUSH DEVELOPMENT CO.
THE BRUSH DEVELOPMENT CO.

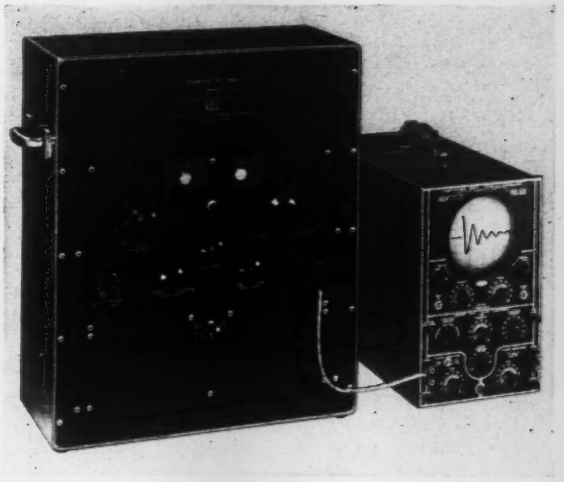
Records Voltage and Current On One Chart!

● This Brush Direct-writing Dual-channel Oscillograph plots starting voltage and current of a fluorescent lamp simultaneously . . . thus aids a leading manufacturer in design and test work.

Use the Brush Magnetic Oscillograph, in combination with the proper Brush Amplifier, to make an immediately available direct chart recording of physical and electrical phenomena. Direct-inking or electric stylus models available. Gear shift provides chart speeds of 5, 25, and 125 mm per second. An auxiliary chart drive is available for speeds of 50, 250, and 1250 mm per hour. Accessory equipment provides event markers where an accurate time base is required, or where it is desirable to correlate events.



RECORDS SIX VARIABLES SIMULTANEOUSLY. The Brush six-channel Magnetic Oscillograph is designed for simultaneous recording of six electrical phenomena, with a chart record immediately available. In this application the results of six different computations of an electronic differential analyzer are recorded. Instrument facilitates multiple strain measurement, vibration analysis, wind tunnel work, circuit analysis, etc. Either d-c or a-c phenomena up to 100 cycles can be recorded.



"PLAYS BACK" TRANSIENTS. The Brush Transient Recorder is designed to record and reproduce transient phenomena of ⅕ second or less. This instrument records transients on tape, then reproduces them for visual analysis on an oscilloscope. Signals can be shown complete, or expanded on the screen to show detail. Electrical transients or other transients which can be converted into electrical impulses can be studied.

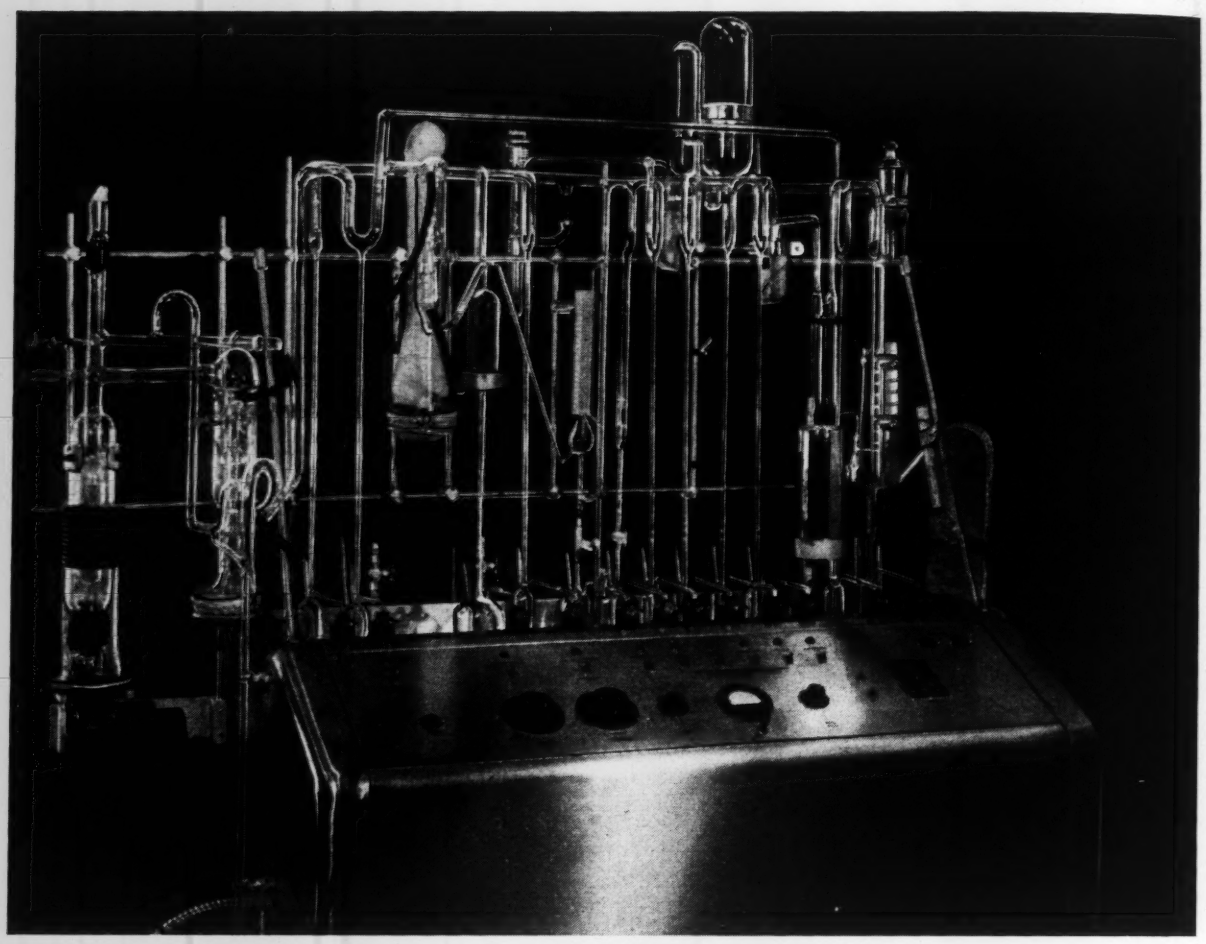
For Bulletin 618 giving details on these instruments, write The Brush Development Co., Dept. A-31, 3405 Perkins Ave., Cleveland 14, Ohio. Representatives located throughout the U. S. In Canada: A. C. Wickman Ltd., Toronto.

THE *Brush* DEVELOPMENT COMPANY

BRUSH

Piezoelectric Crystals and Ceramics
Magnetic Recording
Acoustic Devices
Ultrasonics
Industrial & Research Instruments

Vacuum Fusion Gas Analyzer



A packaged unit to determine the content of oxygen, nitrogen and hydrogen in metals

A wide variety of metals and alloys, including titanium, can be analyzed to determine the amount of oxygen, nitrogen and hydrogen contained either as combined or dissolved gas, in the range from one per cent to approximately 10^{-4} per cent by weight.

Total gas contents of titanium are reported within approximately the same range as for other metals, through the use of certain special techniques.

The apparatus incorporates the best features and techniques reported in the literature or known to our laboratory and has been employed for some time in connection with our own metallurgical research activities.

Operating procedure is relatively simple and can be readily mastered. Installation and final testing is performed by one of our trained analysts.

Write for details of Type 09-1240 Vacuum Fusion Gas Analysis Apparatus.

INDUSTRIAL RESEARCH • PROCESS DEVELOPMENT
HIGH VACUUM ENGINEERING AND EQUIPMENT

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COATING • APPLIED PHYSICS

National Research Corporation

EQUIPMENT DIVISION

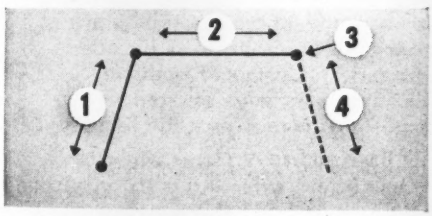
Seventy Memorial Drive, Cambridge, Massachusetts

In the United Kingdom: BRITISH-AMERICAN RESEARCH, LTD., London S. W. 7 — Wishaw, Lanarkshire

If You're Batch-Cooking You Can Use This Inexpensive Control

Here is a recorder-controller planned especially for economically controlling processes like batch cooking. The Gotham Elapsed Time Recorder-Controller does the essential control jobs easily and accurately. First of all, it brings the batch up to maximum holding temperature fast. It holds the batch at that temperature for a predetermined period. It shuts down the process at the end of the cooking period. Those are its three standard functions. Automatic venting or cooling functions can be added. Also available with a pressure, instead of temperature, system.

Write for full information about the Elapsed Time Recorder-Controller and other Gotham Controllers. They're in Catalog 500.



This Is What the Gotham Elapsed Time Recorder-Controller Does

1. Brings controlled variable (temperature or pressure) up to maximum fast.
2. Holds variable at maximum for predetermined period.
3. Shuts down process.
4. Automatic venting or cooling can be added.

Gotham Elapsed Time Recorder-Controller

SPECIFICATIONS

CHART SIZE: 12"

CASE: Standard - black crinkle; smooth black or white may be obtained.

ACTUATION: Vapor, Gas or Mercury for temperature. Pressure elements available.

CHART DRIVE: Spring wound or synchronous motor.

CONTROL SYSTEM: Pilot relay with adjustable sensitivity for 0 to 30% throttling band is standard, two position or 100% throttling band available.

HOLDING PERIOD: Standard 0 to 3 hrs. Other periods available.

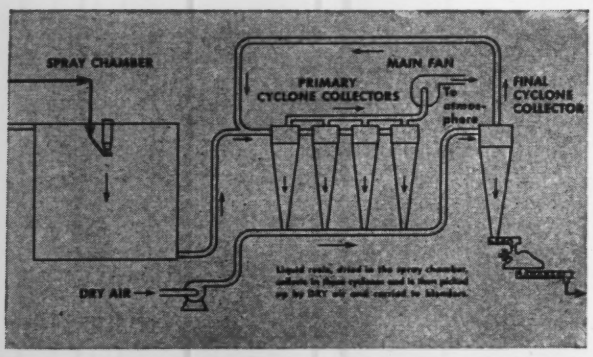
Keep Everything Under Control With Gotham

GOTHAM INSTRUMENTS

Division of AMERICAN MACHINE AND METALS, INC.

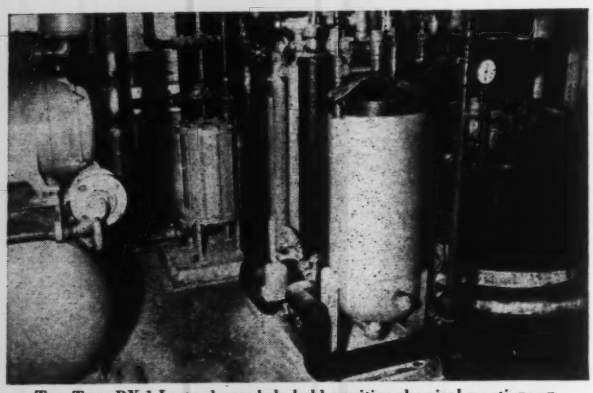
Dept. 2, 233 Broadway, New York 12, New York

LECTRODRYERS are production tools at these American *Cyanamid* Plants



DRY air picks up powdered resin to keep it DRY at American Cyanamid's Wallingford, Conn. plant

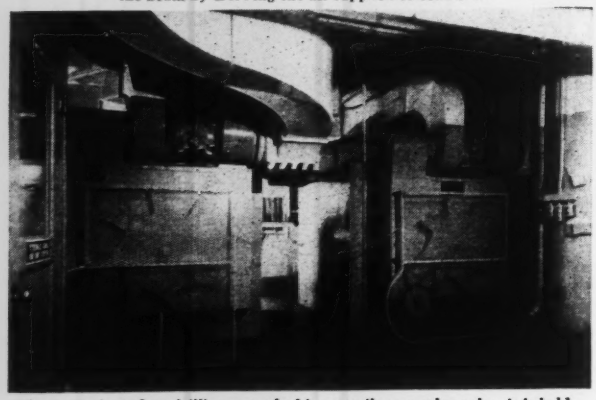
Get molding powders DRY and keep them that way; that's the function of this portion of the production line in this ultramodern plant. There's no moisture in the air that picks up molding powders as they come from the cyclones—no moisture to impair the quality American Cyanamid has compounded into these products.



Two Type BY-1 Lectrodryers help hold sensitive chemical reactions on the beam by DRYing the air supplied to controls.

On instrument air at Calco Chemical Division, Willow Island, W. Va.

No moisture gets into air lines here to condense, form ice, rust or sludge and cause trouble. Two Lectrodryers* designed especially for instrument air work, catch the vaporous moisture which aftercoolers, filters and separators let by. Calco Chemical Division's products are consistently higher in quality, therefore.



Aureomycin and penicillin are packed in a sterile area where the air is held at 6% relative humidity by these Lectrodryers.

Holding humidities constant at Lederle Laboratories Div., Pearl River, New York

Control the quality of air surrounding processes, just as you control materials going into products; this is a rule for quality production at Lederle Laboratories Division, as at the other divisions of American Cyanamid Company. Besides sterilizing the air here, Lectrodryers hold it at a constant temperature and humidity.

You probably have plenty of places where Lectrodryers will help you boost quality and speed production. For help in finding out, write Pittsburgh Lectrodryer Corporation, 330 32nd Street, Pittsburgh 30, Pennsylvania.

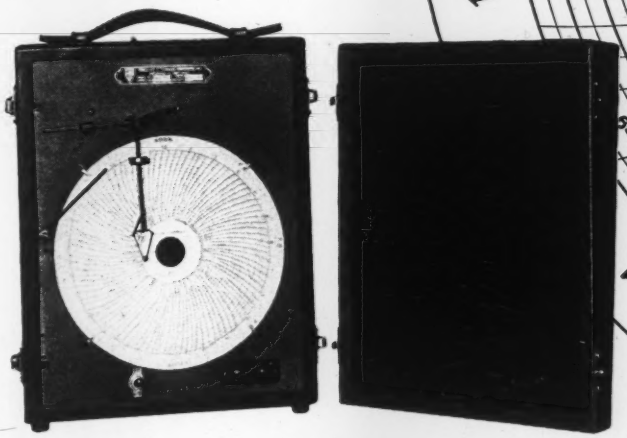
LECTRODRYERS DRY WITH ACTIVATED ALUMINAS

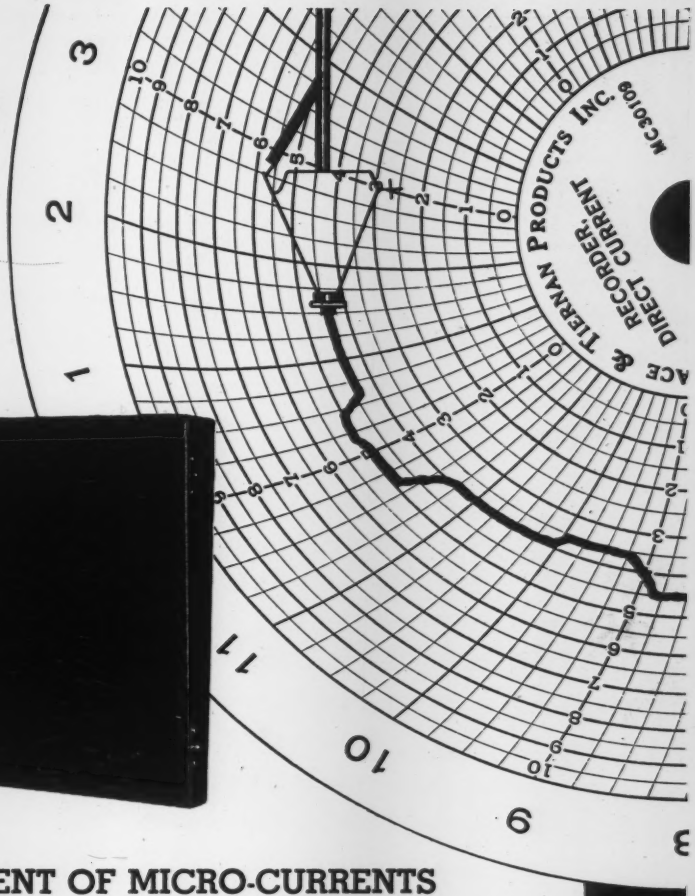
LECTRODRYER

*REGISTERED TRADEMARK U.S. PAT. OFF.

ANOTHER W&T PRECISION INSTRUMENT

THE PORTABLE DIRECT CURRENT RECORDER





FOR THE MEASUREMENT OF MICRO-CURRENTS

The New W&T Portable Direct Current Recorder permits direct recording of minute electrical currents and voltages, as well as certain non-electrical values through the use of pick-ups and amplifiers. The instrument is extremely versatile and possesses a range which permits handling 6.0 amperes and, at the same time, can detect a change of current as low as 1/10 microampere. It is useful in research laboratories and for such applications as communication and electronic circuit analysis, and in thermocouple pyrometry. Brief specifications are:

Type	Moving magnet, interchangeable coil.	Scale Length . .	2½ inches.
Sensitivity . . .	1 part in 1000 of full scale range.	Chart Diameter .	8 inches.
Minimum Range .	0 to 100 microamperes.	Chart Speed . .	1 revolution per 24 hours.
Maximum Range .	0 to 6.0 amperes.	Case	Highly finished hard wood.
Coil Adjusting Range . . .	2.3 to 25 ampere turns.	Size	13" high by 10⅛" wide by 5½" deep.
		Weight	10 pounds.

A-87

Write today for complete details—there's no obligation

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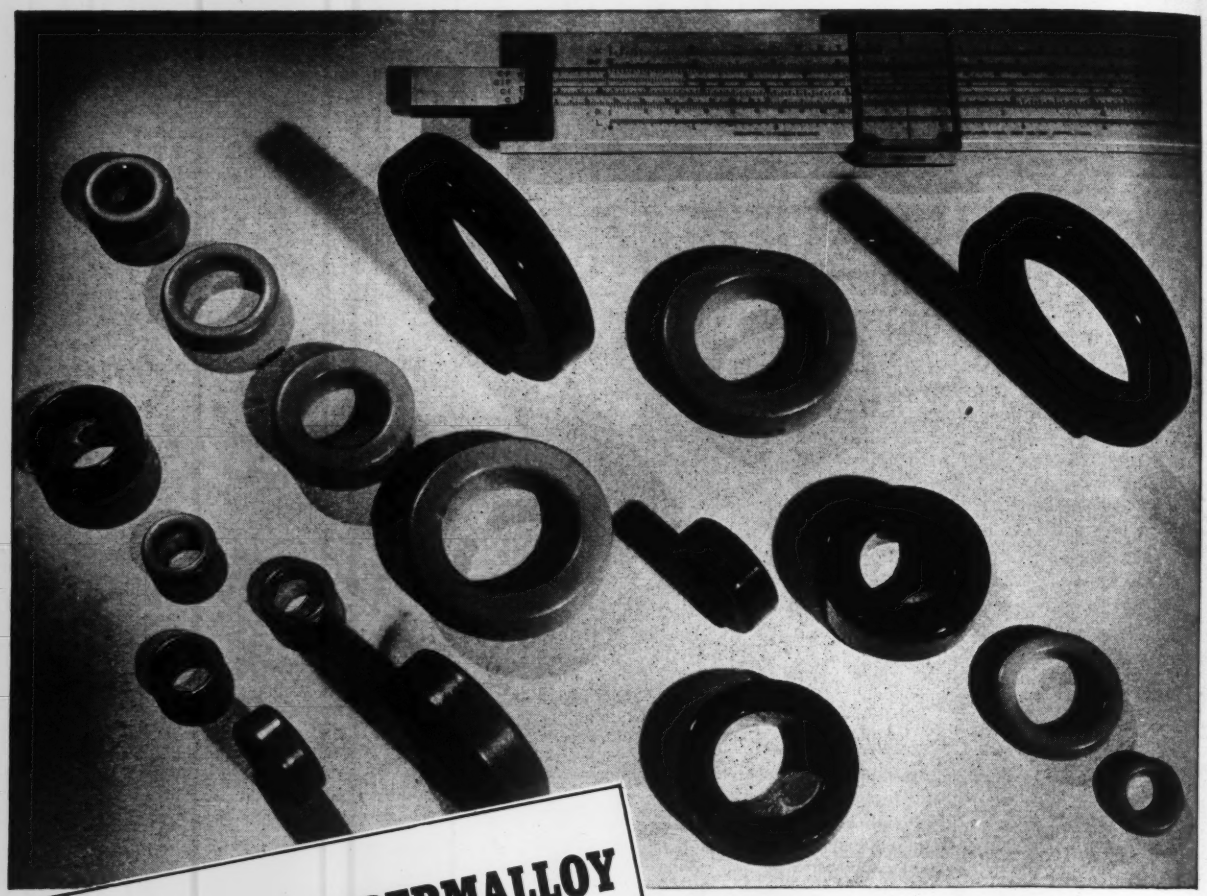
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities



MOLYBDENUM PERMALLOY POWDER CORES*

(New technical data now available)

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 KC

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

- ★ **Furnished in four standard permeabilities—125, 60, 26 and 14.**
- ★ **Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.**
- ★ **These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.**

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

*Manufactured under license arrangements with Western Electric Company

W&D 4127

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

Read pressure, temperature or flow at a distance with USG Pneumatic Receiver Gauges

← **SINGLE RECEIVER GAUGE, *Full Size* (3½")**—Indicates actual temperature, pressure or flow. A Duplex Receiver Gauge contains two springs, also indicates the control setting.

With panel board space at a premium, the popular USG 3½" Pneumatic Receiver Gauge is the answer to your problem. Equipped with a statically-balanced frictionless movement, with precision generated teeth and polished bearings of top aircraft quality, these small size gauges achieve a perfection in performance previously not thought possible of a pressure gauge.

FEATURES

Ranges:	3 to 15 p.s.i.g. stocked, 3-18 p.s.i.g. also available.
Scale:	A variety of scales available.
Case Diam.:	3¾"
Bezel Opening:	3½"
Pressure Elements:	Phosphor Bronze, AAA width, stress-relieved.
Movement:	Aircraft quality — phosphor bronze and stainless steel.
Adjustments:	±1% maximum linearity adjustment with adjustable tip; micro-adjustable pointer permits rotation with respect to pinion for zero adjustment.
Stops:	Zero and over-range.
Case:	Drawn steel, black crinkled finish, bevelled glass.
Socket:	Extruded brass.

SINGLE OR DUPLEX TYPES—The USG Receiver Gauge is graduated to the same scale as the transmitter gauge yet operates at a very small pilot pressure. It is available with a single spring or double spring (Duplex Receiver Gauge).

GAUGES CARRIED IN STOCK—USG Receiver Gauges are stocked without dials in the range of 3-15 lbs. This permits easy assembly and quick shipment of gauges with dials calibrated to your choosing. Single-spring gauges are available in ¼" low male or center back connection. Duplex gauges are available in low back connection with ⅛" or ¼" male pipe thread and 5/16-28 tubing connection.

United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

UNITED STATES GAUGE

USG

Quality Gauges Engineered for Enduring Accuracy

PRODUCTS OF UNITED STATES GAUGE... Absolute Pressure Gauges • Aircraft Instruments • Air Volume Controls • Altitude-Gauges • Boiler Gauges • Chemical Gauges • Mercury, Gas, and Vapor Dial Thermometers • Glass Tube and Industrial Thermometers • Flow Meters • Inspectors' Test Gauges • Precision Laboratory Test Gauges • Marine, Ship and Air-Brake Gauges • Voltmeters • Ammeters • Welding Gauges

OTHER DIVISIONS OF AMERICAN MACHINE AND METALS, INC., AT SELLERSVILLE, PA.:
GOTHAM INSTRUMENTS AND AUTOBAR SYSTEMS

The World's LARGEST BUILDING JOB

NEEDS

INSTRUMENTATION ENGINEERS

. . . experienced in repairing, making and calibrating industrial instruments used on the BILLION DOLLAR SAVANNAH RIVER PROJECT.

DU PONT

. . . is building this huge installation for the U. S. Atomic Energy Commission. It offers capable instrumentation men:

★ *54 Hr. Work Week with Overtime Pay*

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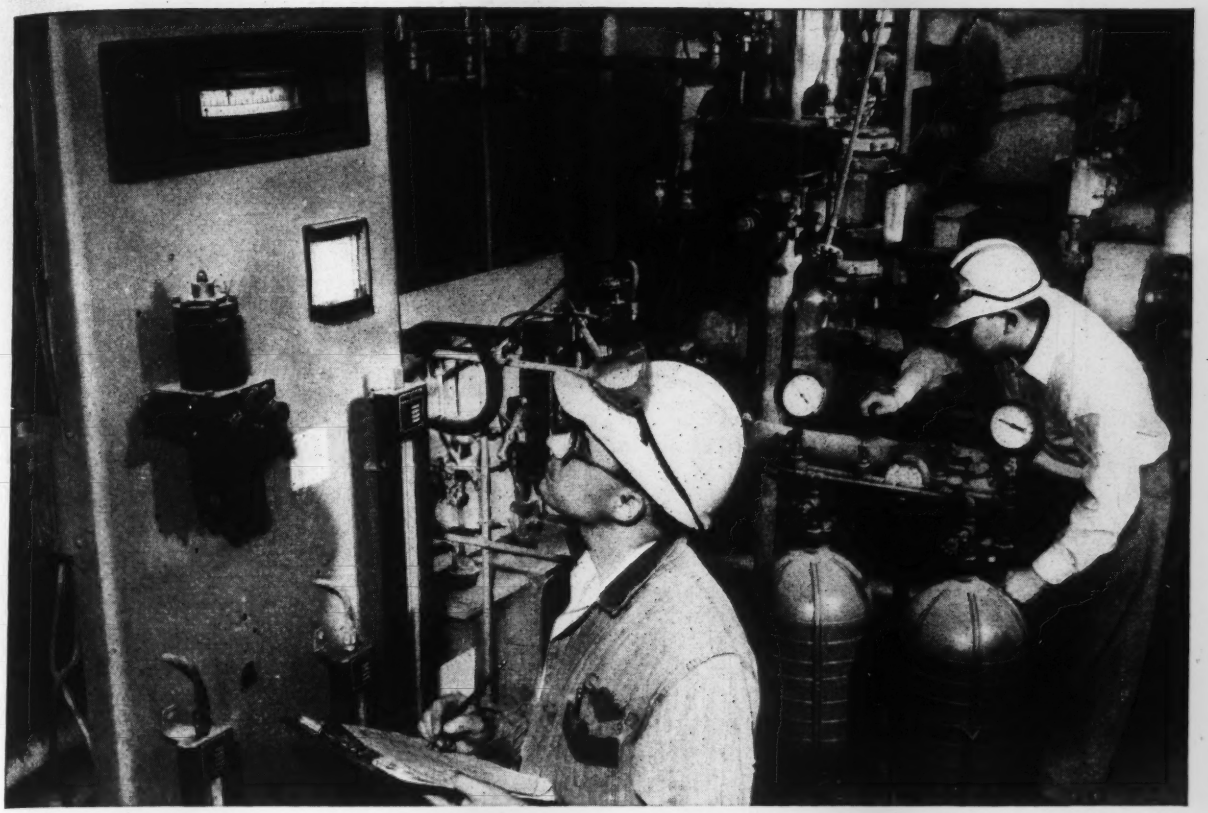
CONSTRUCTION RECRUITMENT SECTION
P. O. BOX 117 AUGUSTA, GA.



CHEMICAL PLANT HCL FUMES HAVE HAD NO EFFECT ON THIS PYROMETER'S ACCURACY; ABOVE, OPERATOR TAKES PYROMETER READING

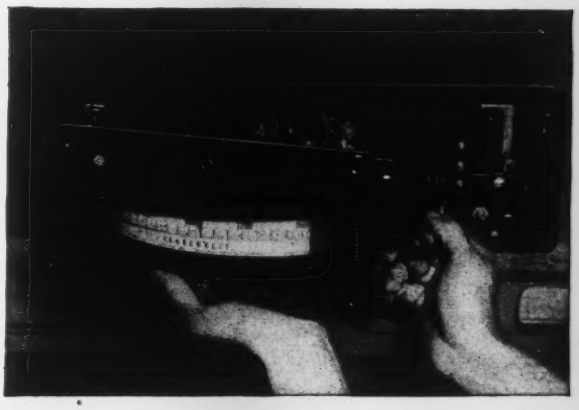
"Extremely Corrosive Atmosphere— No Change in G-E Pyrometer Accuracy"

The calibrated accuracy of General Electric pyrometers is within ¾ of 1 per cent of full scale. And these instruments are built to take excessive punishment. A large eastern chemical manufacturer writes: "We use the HP-3 pyrometer to control the temperature of heat transfer oil. The surrounding atmosphere is extremely corrosive, due to hydrochloric acid fumes—yet there has been no sign of operational difficulty or failure."

CLOSE TEMPERATURE CONTROL. Any change in temperature, even as small as 0.1% full scale, starts immediate control action. All pyrometer models are available in a variety of temperature ranges in the 0-3000 F span.

HIGH FLUX DENSITY is provided by a 3¼-pound alnico magnet. It also allows large air gaps. The lightweight moving system effectively resists shocks and vibration.

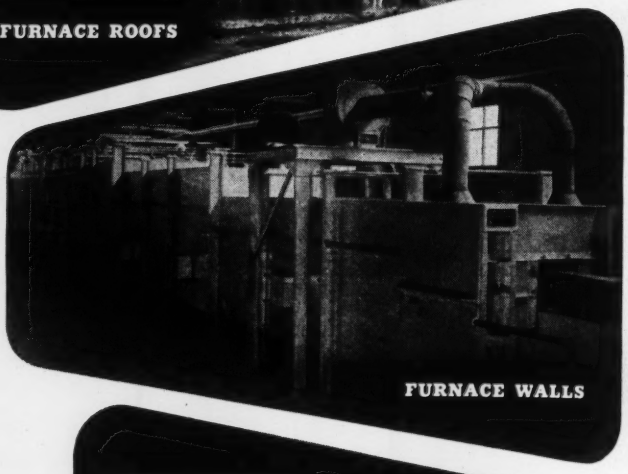
FOR MORE INFORMATION, call your G-E representative or write for Bulletin GEC-713. General Electric also offers a complete line of thermocouples—described in GEC-714. Write Section 602–238, General Electric Company, Schenectady, New York.



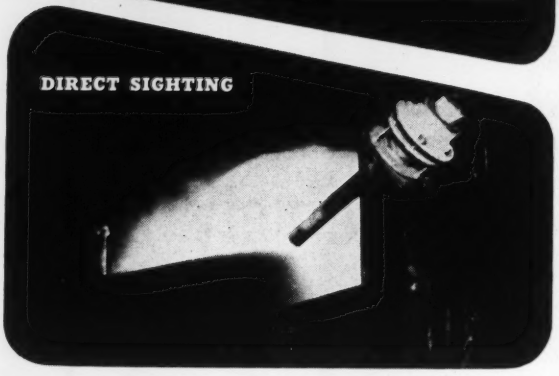
FOUR TYPES AVAILABLE—indicating, protecting, two- and three-position control forms. Both flush and surface mountings can be supplied; wide variety of temperature ranges is available.

GENERAL ELECTRIC

This RAYOTUBE suits all locations COOL OR HOT



FEATURES:
Quick installation
" sighting
" response to temperature



Here is the radiation-sensing unit for 9 out of every ten radiation-pyrometer uses. It adds the storekeeping advantages of smaller instrument inventory to the operating advantages* of all Rayotubes. Many hundreds of this type are now in use. Among its features:

1. Easy to install because it needs no water-jacket unless the head housing itself (shown above) reaches interior temperature of 350 F. Even then, no harm is done below 450; accuracy decreases above 350, but returns fully as temperature drops. In practical operation, even 350 is reached on very, very few installations.

When replacing a present jacketed Rayotube with this type, it is not necessary to tear out the jacket and piping. Simply insert Rayotube in jacket and turn off water if no longer needed.

2. New, quick-sighting optical system shows exact area from which temperature is being recorded. This is especially helpful when instrument is being positioned to point down an open-end tube and measure directly the surface temperature of parts being heated.

3. Can be used with Speedomax electronic instruments as well as with Micromax equipment—which blanket every temperature-recording and/or controlling job in industry.

This Rayotube is No. 8890. Any L&N office, or headquarters at 4955 Stenton Ave., Phila. 44, Pa., will send details on request.

LEEDS & NORTHRUP
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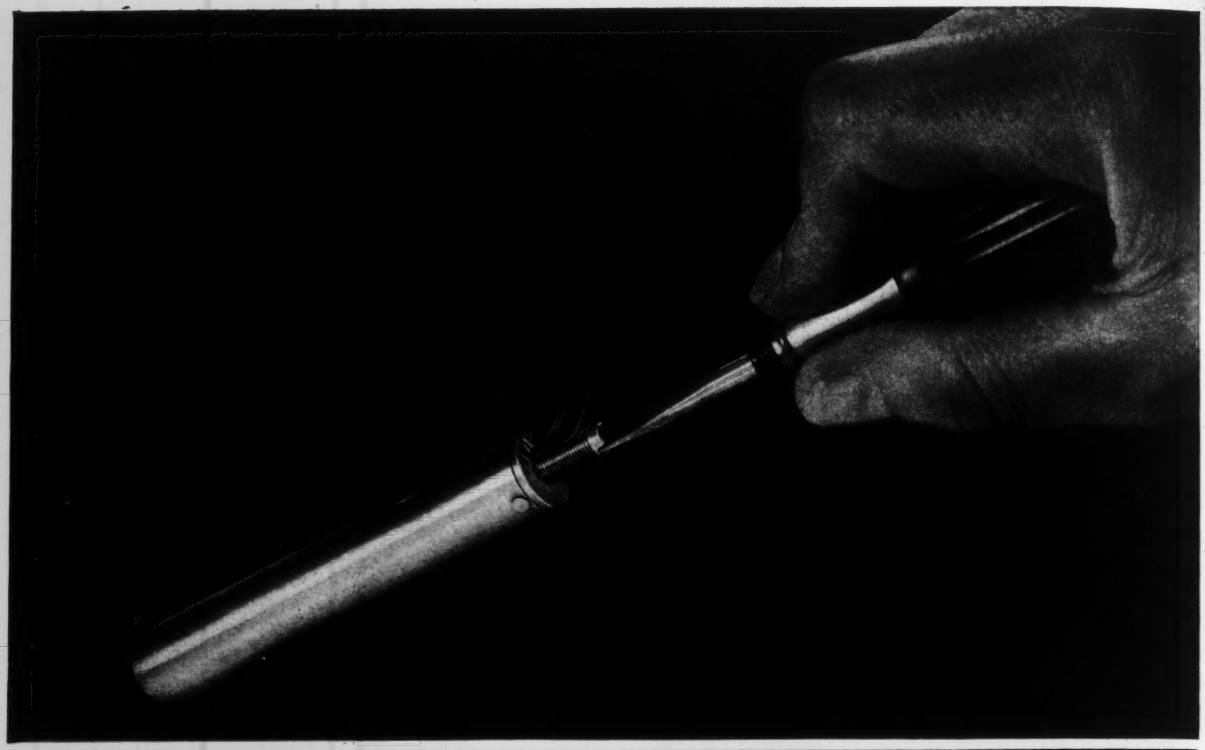

The Superior Tube That Keeps Cool in a Hot Spot

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An example is illustrated above. The customer, Fenwal, Incorporated of Ashland, Massachusetts, manufactures THERMOSWITCH® industrial thermostats; Aircraft temperature controls, fire and overheat detectors; DETECT-A-FIRE® fire detectors. All of these products use stainless steel tubing. Before consulting with us an extra machining operation on the inside diameter was required. The tubing used needed a special temper for softness.

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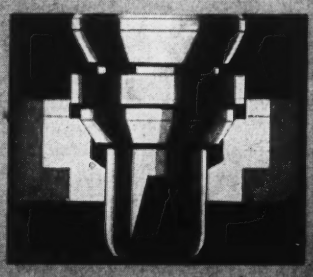
V-PORT DISC is scientifically designed. Shut-off seating surface is entirely removed and separate from the controlling V-Ports. Wire-drawing and cutting action are minimized. No separate shut-off valve needed. Hancock Flocontrol Valves are "2 in 1" valves. The separate seating surface on the V-Port disc gives you a shut-off valve as well as a control valve.



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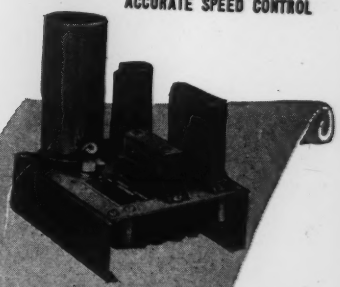
Whatever your frequency problems may be, our engineers are ready to cooperate.

When requesting further details, please specify the Type Numbers on which information is desired.



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Input, 50-100 cyc., 275 W.

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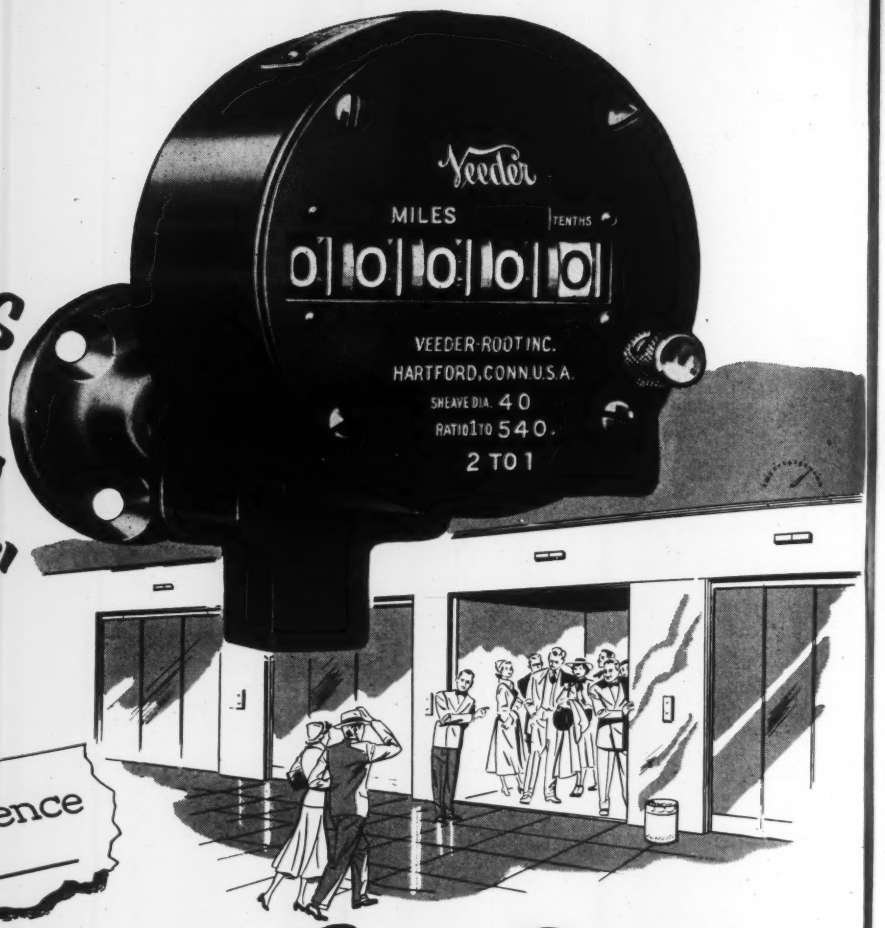

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Here's How to Erase Smoke Troubles

VIOLATION OF SMOKE ORDINANCE

LOSS OF FUEL ECONOMY

BAD COMMUNITY RELATIONS

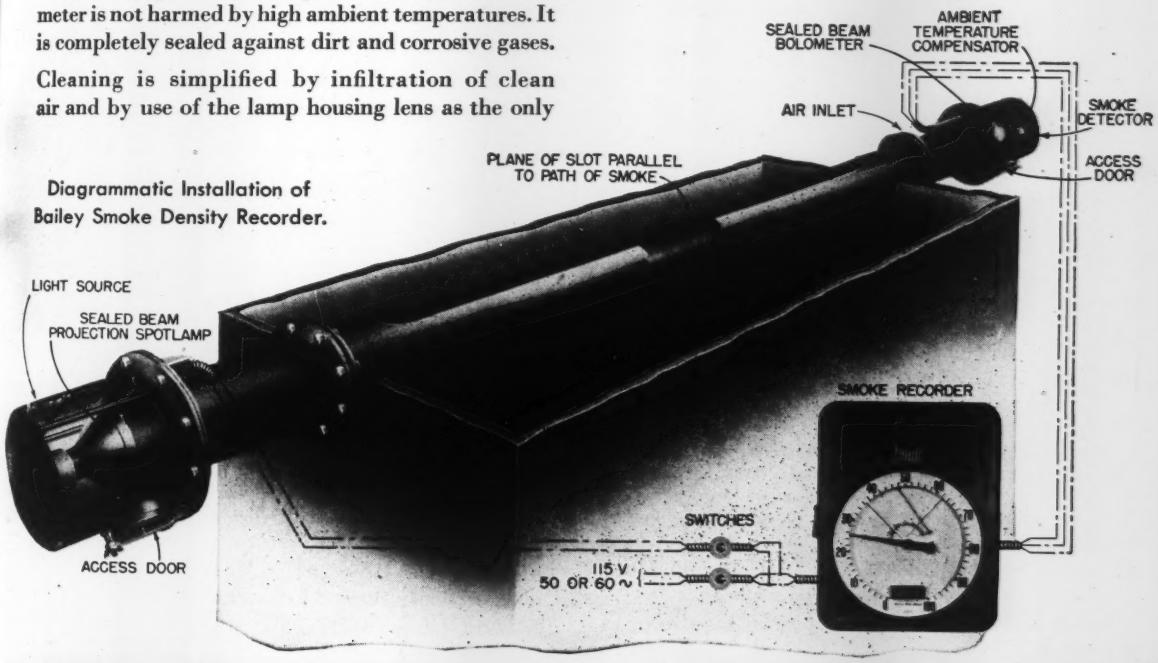
★ One of your first steps in erasing these troubles which result from excessive smoke, should be the installation of a Bailey Smoke Density Recorder. This 24-hour recorder is not an ordinary photo-cell instrument. Instead it detects smoke density by a Bolometer which is simply a sturdy tungsten filament and a parabolic mirror, mounted in a standard sealed beam automobile head lamp housing.

In using this simple, unique smoke detector, you do not have to provide cooling devices since the Bolometer is not harmed by high ambient temperatures. It is completely sealed against dirt and corrosive gases.

Cleaning is simplified by infiltration of clean air and by use of the lamp housing lens as the only window between the Bolometer and the gas passage.

It's easy to secure and maintain alignment of the sealed beam light source with the Bolometer since they are mounted at opposite ends of a slotted pipe which extends across the smoke passage.

For complete information on how you can profitably use this unique instrument to erase your smoke troubles, ask for Bulletin 211, "Bailey Smoke Density Recorder".



Diagrammatic Installation of Bailey Smoke Density Recorder.

G-29

BAILEY METER COMPANY

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BAILEY METER COMPANY LIMITED, MONTREAL, CANADA

Let Bailey Smoke Density Recorders Watch Your Stacks

Here's why it pays to know your HSM

HONEYWELL SUPPLIES MAN

C. J. SMOLINSKE, Honeywell Supplies Man in the Indianapolis area, helps check connections of special purpose thermocouple wire on a jet engine test in the CAA Laboratories, Indianapolis. Highly useful in this and many other applications are the new thermocouple wires recently added to the ever-expanding line of Honeywell supplies. An exceptionally wide range of temperature is now covered by new wires with the following insulations: plasticized vinyl chloride insulation for service from —20 to 225° F.; non-impregnated glass insulation for use up to 1200° F.; and fibrous silica insulation for temperatures as high as 2000° F.

Special purpose wires are but one part of the complete supplies service afforded by the HSM Plan. In literally hundreds of ways, this plan can add new convenience and economy to *all* your pyrometer supplies buying!

Find out now, how planned buying—*the HSM way*—can assure you the best in quality, availability and price. Your local Honeywell Supplies Man will be glad to explain how this plan can work for you. Call him today . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4583 Wayne Ave., Philadelphia 44, Pa. Stocking points in Philadelphia, Cleveland, Chicago, Atlanta, Houston, Los Angeles and San Francisco.

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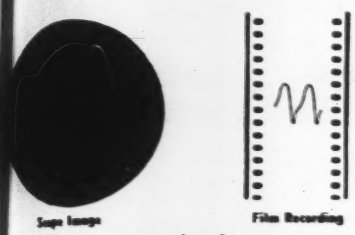
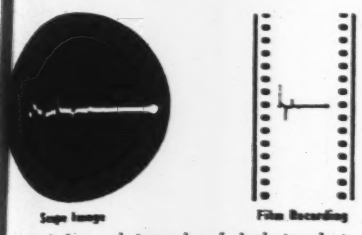
● *Important Reference Data*

Write for new Pyrometer Supplies Buyer's Guide No. 100-4

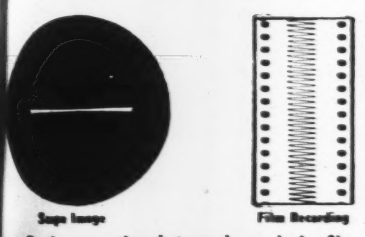
Want an oscilloscope camera NOW?



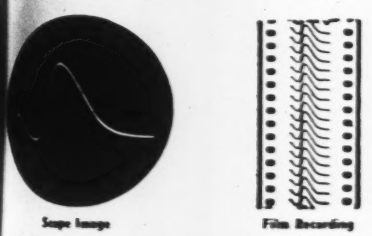
1. Single-frame photography of stationary patterns using a continuously running sweep.



2. Single-frame photography of single transients using a single sweep.



3. Continuous-motion photography employing film motion as a time base.



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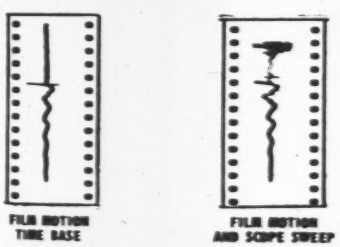


5. Continuous-motion photography employing combination of film motion and oscilloscope sweep as a time base.

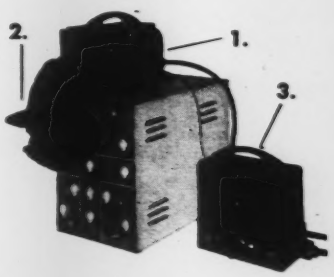
Complete information about applications and operation of both the Fairchild Oscillo-Record Camera and the Fairchild-Polaroid Oscilloscope Camera is available. Write today to *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, New York, Department 120-15F.*

Fairchild Oscillo-Record Cameras are now available *from stock* for immediate shipment. With these units you can make *permanent* photographic records of oscilloscope traces, thereby eliminating possible errors in making hand sketches from memory. In time-saving and convenience alone, these cameras will pay for themselves many times over.

FAIRCHILD OSCILLO-RECORD CAMERA IS UNUSUALLY VERSATILE

Users of the Fairchild Oscillo-Record Camera like its versatility. Designed for both still and continuous-motion photography on 35-mm film, it records non-recurring phenomena that are too rapid for visual study, others that are so slow that continuity is lost, and the occasions where very high-speed transients are combined with very slow-speed phenomena. For some idea of the types of jobs this instrument can do, study the examples at the left. Each solves a particular problem. Oscillo-Record camera users especially like its:

- **CONTINUOUSLY VARIABLE SPEED CONTROL** — 1 in./min. to 3600 in./min.
- **TOP OF SCOPE MOUNTING** that leaves controls easily accessible.
- **PROVISION FOR 3 FILM LENGTHS**—100, 400 or 1,000 feet.



1. Camera, 2. periscope, 3. electronic speed control. Accessories include 400- and 1,000-ft. film magazines, magazine adaptor and motor, universal mount for camera and periscope, binocular split-beam viewer.

FAIRCHILD TAKE-UP CASSETTE FOR SHORT RUNS

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FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

Here's why it pays to know your HSM

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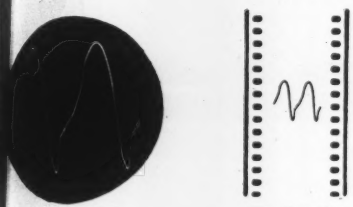

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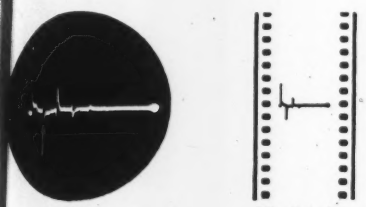

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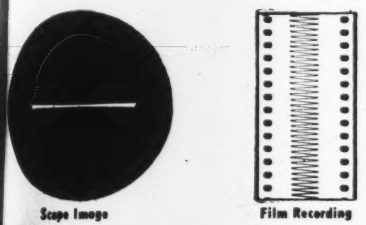

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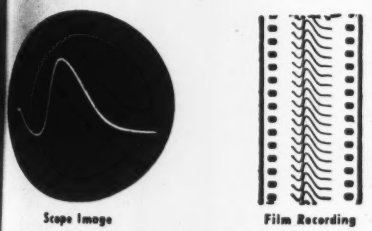

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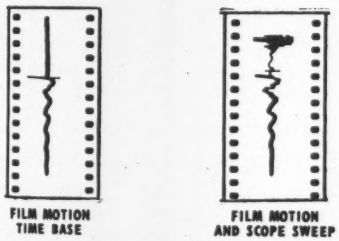

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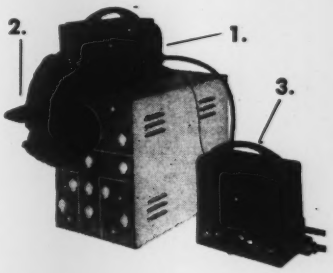

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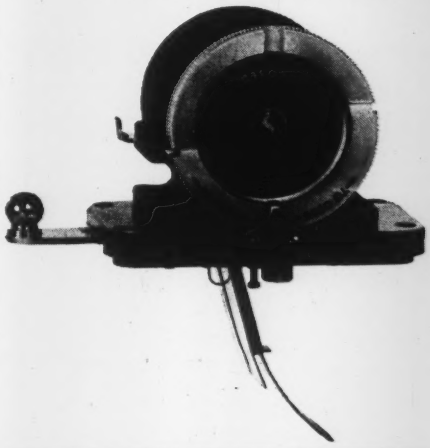
FAIRCHILD TAKE-UP CASSETTE FOR SHORT RUNS



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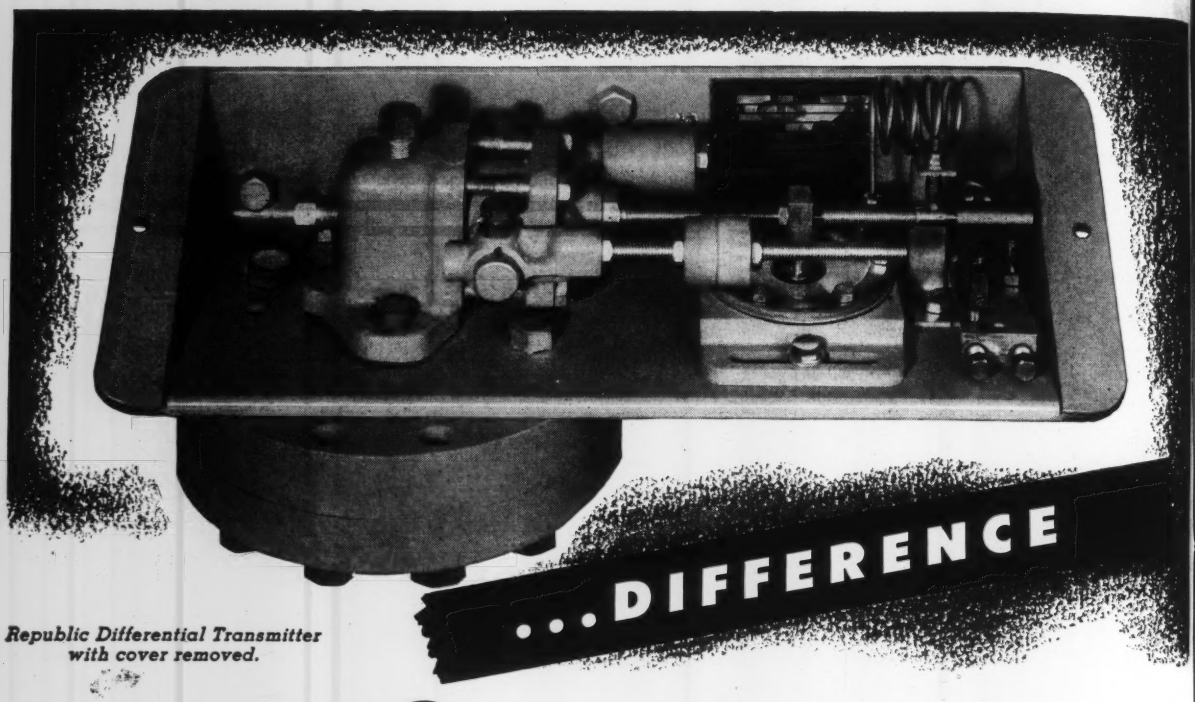

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announces an entire issue devoted to AUTOMATIC CONTROL

to be published in September, 1952

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TABLE OF CONTENTS (in part)

THE FEEDBACK CONCEPT — **by Arnold Tustin**
The author, at the University of Birmingham, England, will show how the application of the feedback concept, a universal principle of nature and of social organization, makes industrial processes control themselves.

THE STATE OF THE ART — **by G. S. Brown and D. G. Campbell**
This article will assess the progress of automatic control technology to date and project its future course. The authors, at M. I. T., are also the authors of the definitive engineering treatise on automatic control.

CONTINUOUS PROCESS CONTROL — **by Eugene Ayres**
The push-button plant, self-operating under the direction of one or two men at a central control panel, is already a reality in chemical and petroleum industries. The author is at Gulf Research and Development Corp.

DISCONTINUOUS PROCESS CONTROL — **by William Pease**
Automatic control is making progress in the metal-working industries, where problems of speed and versatility have been difficult to meet. The author, at M.I.T., has designed a feedback-controlled milling machine.

INFORMATION — **by Gilbert King**
Automatic control theory provides powerful new ways to make sense of the huge volumes of information which must be coped with at so many points in industrial management. The author is at Arthur D. Little, Inc.

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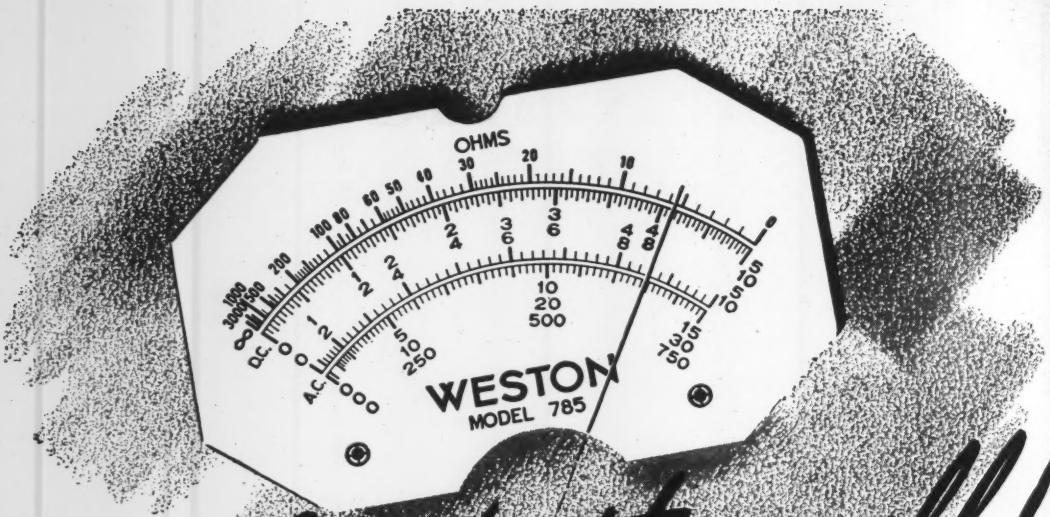

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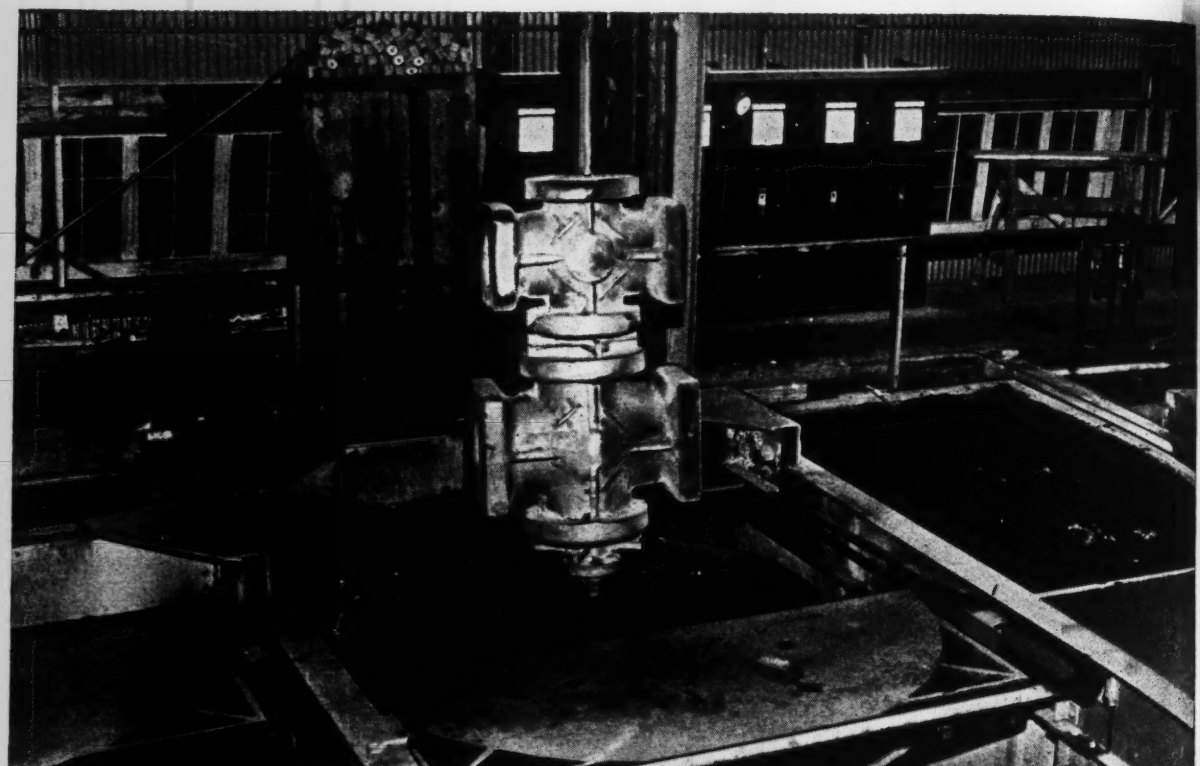

Part of heat-treating dept., Texas Electric Steel Casting Co., Houston. Valve body casting leaving furnace after slow cooling. All furnace temperatures are controlled by Micromax instruments in background.

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Editorial Comment

On Starting an Instrument Department

(A revision—and modernization—of the editorial bearing the same title which appeared in our March 1947 issue.)

Dear Mr. ———: Your inquiry on starting an instrument department was the latest of many of its kind to which —of necessity—only brief replies were sent. This time, however, we have spent a few hours putting down data and compiling a list of references—not only for you but for others who will read this in our next issue, because this letter will be run as the June editorial.

Up to recently, someone in this office replied briefly, giving as the only reference our 1932 book "Fundamentals of Instrumentation," of which the last chapter is a compendium of seven sections by seven authors, under the general title "The Plant Instrument Department—Its Organization and Equipment." This book has been out of print for several years. Its procurement —even on loan—is becoming more and more difficult. We are at work on a new edition but you want information promptly. Hence the long list of articles appended to this letter, in addition to the letter itself.

Calibration, etc.

You will find many lists in the appended bibliography but we cannot give you one single list. The reason is that there does not exist a list of reference standards, calibrating devices, and other equipment suitable for *any* Instrument Department and at the same time within the budget of an "average small" Instrument Department. Moreover, the question what is an "average small" Instrument Department cannot be answered exactly because no two departments are alike. Yours, for example, is closer to a chemical industry than to, say, the textile industry. I have often "stuck out my neck," however, in asserting that *there is one universal principle* which, if observed, will enable any department to determine its minimum requirements. It is simply the principle that each working instrument should be checked periodically against a "standard," which "standard" need not be an elaborate and expensive National Bureau of Standards instrument or apparatus, but only an instrument *more accurate than the working instruments by one order of magnitude*, or, as the common expression goes, by "one more decimal."

In other words, if you have a number of indicating and recording thermometers all desired to be accurate to two degrees Fahrenheit and if the temperatures they measure do not exceed the range of 32 F. to 600 F., then all you need to check them is four or five laboratory-grade thermometers accurate to 0.2 F. and several baths in which to immerse both the working thermometer and standard thermometer. These baths or chambers need not be expensive precisely-adjustable constant-temperature baths such as those in research laboratories, but can be simple and inexpensive. The essential is not that the temperature should be controllable or adjustable to a small fraction of a degree but simply that the temperature remain CONSTANT while the readings of the working thermometers are being compared with the readings of the certified thermometers. For this kind of constancy the principal requirements of a bath (water, oil or salt) are ample capacity, stirring and insulation. In addition to a bath, a steam chamber can be easily contrived from a four-foot length of 6-inch pipe.

For calibrating ordinary working pyrometers of the thermoelectric type, likewise, a portable potentiometer, one or two certified thermocouples, a Thermos flask for ice-point reference, and one small laboratory oven should suffice—but be sure to follow the instructions accompanying the portable potentiometer.

For calibrating pressure gages, *including the differential manometers of most flowmeters*, two or three simple mercury and water columns, plus a dead-weight tester or an "inspector's gage" for the higher pressures.

Working tachometers can easily be checked by any of several readily-available chronometric tachometers or by using a narrow-range frequency meter in conjunction with a small a-c. generator (or one of various "benches" or "stands" made for the automotive and air transport industries).

For calibrating CO and CO_2 working instruments there are various styles of laboratory apparatus—some of them portable but remarkably accurate when properly used.

For calibrating radioactivity-sensitive primary elements, the NBS and the AEC have made available various standards, with which you no doubt are familiar.

And so on for other basic classes of measurements, the result being not a "laboratory" but simply a group of independent calibration benches.

The next stage usually consists in the acquisition of standards of length, mass, etc.: gage blocks, micrometers, a laboratory balance, a Wheatstone or Mueller bridge, a microscope, a mercurial barometer, etc. With such equipment at hand, in addition to the items already mentioned, you have a laboratory section, or standards section, within the Department—and it should be operated by at least a junior physicist, unless it is under the direct supervision of a Department Head who is himself either a physicist or an engineer possessing the requisite special knowledge, preferably gained by experience.

Maintenance, etc.

You request a list of equipment for maintaining and servicing your plant instruments of "various makes." For bare maintenance, a small new Instrument Department usually starts with hand tools only. If the instrument manufacturers' printed instructions are faithfully observed, a good assortment of pocket tools will be quite sufficient to keep them in good condition in *your* plant. We state this without hesitation because we are sure that you have employed ex-service men who had been given Instrument Technician training. These men, under proper supervision,

CORRECTIONS

On page 596 of the May issue, in the article Valve Control of Liquid Flow by Russell Milham and Allan Catheron, there appears the equation:

$$(\Delta p_s - \Delta p_v)\Delta p_v.$$

Because of printer's error, the equation is incorrect. It should be:

$$(\Delta p_s - \Delta p_v)/\Delta p_v.$$

On page 565 of the May issue, last words of first line of first footnote should read '"Flow Measurement",' not '"Four Measurement".'

Have you a copy of the Jan. 1928 *Instruments?*

(or, perhaps, of all twelve issues of Vol. 1—Jan.-Dec. 1928?)

Yes, we know that there are unmutilated copies of Vol. 1—and all subsequent volumes—in libraries; but we are after individual owners. Please write to Historical Section, The Instruments Publishing Company, 921 Ridge Avenue, Pittsburgh 12, Penna.

can maintain your industrial instruments in good condition—if these instruments are not abused in your shops. (By the way, are the heads of your operating departments instrument-minded? Also, are there instrument-trained men in *all* of these departments?)

"Servicing" is quite a flexible term. To most Instrumenticians, however, it covers much more than maintenance, for it includes field and test-stand adjustments (even critical adjustments) and some repairs, but it does not include the advanced or major repairing which involves making parts, refilling tube systems, etc. Therefore we cannot furnish you the list of equipment for completely servicing all your instruments. Being an old *Instruments* subscriber, you know that skill and experience are much more important than special equipment. Although you do not list electrical indicating instruments and give us the impression that you will send them back to the factory for servicing, we recommend Spencer's "Maintenance and Servicing of Electrical Instruments" published by our company: the new 272-page third edition is well worth its three-dollar price.

Organization

When your maintenance and servicing equipment overflows a tool kit and includes a small lathe, a drill press, a grinder, a welding outfit, etc.—when it requires benches—this expansion will mark the second stage—just as with your calibrating facilities. Then, the Department will be divided into a *laboratory* and a *shop*, perhaps still in the same room but sharply separated functionally. This functional division is important. Moreover, as the Department grows, there will be a third function, namely, *office work*, keeping records of all the working instruments in your plant and providing for their calibration at regular intervals.

We must repeat, however, that no two Instrument Departments are alike, even when they are new and small—*especially* when they are new and small, for then it usually is one man's personality, his relations with top management, his ability to "sell" his Department, and other intangible factors, that determine the initial investment and the plans for future expansion.

Bibliography

You will find equipment lists—and much other useful information—in the numerous articles we published on plant Instrument Departments (and Testing Departments, etc.). Herewith is a partial list: In the last column, "L" indicates that *lists* are included; "T" indicates that *training* of personnel is discussed; "O" that departmental *organization* is discussed; "F" refers to *functions* of the department; "E" to special *equipment;* "M" to *maintenance;* "S" means that the department is in a *school.*

If your *Instruments* file does not go back to 1932 you can look up the older articles in the nearest library that has *Instruments* files or you can order photostats or microfilms. A word about the articles by the undersigned in 1936 and 1937: these are some of the articles in a series entitled "*Instruments* Readers at Work" and, as you progress in building up your Department, you will do well to correspond directly with some of these men, also with some of the other large-company Instrument Department heads who have written articles cited in the list. It is highly probable that each one has a collection of mimeographed or printed matter pertaining to his Department, from which he can conveniently spare some for outside distribution. They all are fine men—helpful and considerate as well as top-flight Instrumenticians.

Cordially yours,
M. F. Behar, *Editor*

Year	*Month*	*Author*	*Co. whose dep't is described*	*Spec.*
1932	Feb.	R. W. Brown	Firestone T & R Co.	O, T
1935	Nov.	G. P. Bosomworth	Firestone T & R Co.	T
1936	Jan.	M. F. Behar	Westinghouse (plant)	L
	Feb.	M. F. Behar	Bantam Ball Bearing Co.	L
	Mar.	M. F. Behar	Dow Chemical Co. (Physical Lab.)	L
	Apr.	M. F. Behar	Pittsburgh Plate Glass Co.	L
	Apr.	R. C. Kennan	Brown Instrument Co. (Training Dep't)	T
	May	M. F. Behar	Gulf Refining Co. (Neville Island Ref.)	L
	June	M. F. Behar	Pittsburgh Testing Laboratories	L
	July	M. F. Behar	Navy Yard, Washington, D. C.	L
	Aug.	M. F. Behar	H. J. Heinz Co.	L
	Sep.	M. F. Behar	Airco Laboratory, Jersey City	L
	Oct.	M. F. Behar	Duquesne Works (Carnegie-Illinois)	L
	Nov.	M. F. Behar	Driver-Harris Co. (Quality Control)	L
	Dec.	M. F. Behar	Nat'l Radiator Corp. (Research Dep't)	L
	Dec.	A. C. Moon*	Atlantic Ref. Co. (Phila. Refinery)	O
1937	Jan.	A. C. Moon*	Atlantic Ref. Co. (Phila. Refinery)	T
	Jan.	M. F. Behar	Westinghouse E. & M. Co. (Labs only)	L
	Apr.	M. F. Behar	Good Housekeeping Institute (Lab)	P
	May	Carlos De Zafro	N. Y. University Gage Lab.	L
	July	M. F. Behar	Bristol-Myers Co.	L
	Aug.	Walton Forstall	Philadelphia Gas Works Co.	O
	Aug.	M. F. Behar	W. B. Driver Co.	L
	Dec.	M. F. Behar	Pacific Gas & Electric Co. (Lab.)	L, E, O
1938	Mar.	W. G. Egnor	G-E Co. (Calibration Equipment)	C
	Apr.	W. R. Gilbert	Weston Elec. Ins. Corp. (Calibration Equip.)	C
	May	R. L. Strode	G-E (Motor Testing)	L
	May-Sep.	W. W. Dulmage	Ford Motor Co. power plant (five articles)	L
1939	Apr.	C. B. Cochran	Charleston Trade School	S, T
	Dec.	Fred Hunter	United Air Lines (base)	P
1940	Jan.	Ralph Rand	Texas Co., Casper, Wyo., refinery	O
1941	Oct.	Carl Nisbet	Delta Airlines (base)	O
	Oct.	Morey Eggleston	Western Air Lines (base)	E
	Oct.	Hugh Davis	TWA (base)	T
1942	Jan.	George L. Seavy	Boston Gas & Fuel Co.	E
	Mar.	Philip Ewald	ESMDT Course	T
	Apr.	Robert H. Burck	American Airlines (base)	T
	Apr.	Carl Nisbet	Delta Airlines (base)	T
	Apr.	W. P. Danke	TWA Instr't Dep't.	O
	July	R. G. Ojers	Spartan School of Aeronautics Instr't Dep't	O, S
	Sep.	M. L. Clarke	Bell Labs Instrument Bureau	O
	Sep.	C. S. Gooch	Shelby Aero School	T
	Oct.	C. H. Smith	Chicago Aero School	T
	Dec.	W. J. Watkins	Am. Sch. of Aircraft Instruments	T
1943	Feb.	Elden G. Chapman	Spokane AAF Instr't Shops	T
	Apr., June, Nov.	R. A. Bowman	"Ideal" gage dep't equipment	L, E
	Oct.	Harry Gollob	Standardized courses	T
1944	Jan.	D. J. Bergman & G. G. Gallagher	Universal Oil Co.	O
	Jan.	G. P. Bosomworth	Firestone T & R	T
	Jan.	R. W. Cermak	Dow Chemical Co.	T
	Apr.	V. H. Hiermeir	(Typical oil refinery instr't dep't)	O
	Nov.	J. W. Lankford	CAA Mechanics' Certif.	T
1945	Feb.	Mrs. M. M. Gilbert	Bell Lab. elec. instr't calibration	C, L
	Nov.	SPECIAL ISSUE on Instrumentation and the University but containing many industry discussions		O, T
1946	May	F. H. Trapnell	Eng'g Dep't, duPont	O
	Oct.	H. F. Moore	Standard Oil Co. of N. J.	O, L
	Oct.	H. C. Frost	Corn Products Ref. Co.	E
	Nov.	J. W. Graeb	Canada's synthetic rubber plant instr't dept	O
	Dec.	Joseph Manuele	Westinghouse (Quality Control Dep't)	O
	Dec.	Roger L. Geer	Cornell University Instrument Course	S, T
1947	Feb.	W. H. Fortney	Humble O & R Co. (Baytown Ref'y)	O, L
	May	Paul G. Exline	Gulf Research and Development Co.	O, E, C
	Oct.	J. G. Kerley	Shell Oil (all plants)	O, F, T
1948	May	George A. Larsen	The Texas Co. (Lockport Refinery)	T
	May	George A. Larsen	The Texas Co. (Lockport Refinery)	O, E, M
1949	Aug.	J. Johnston, Jr.	DuPont (Ind. & Eng. Div.)	O, F
	Sep.	Hart U. Fisher	Monsanto Chemical Co.	C
	Nov.	W. H. Fortney	Humble Oil Co.	O
	Nov.	W. D. Wood	Taylor Instrument Companies	C, E
	Dec.	J. G. Kerley	Shell Oil Co. Instr. appl. research	
	Dec.	C. H. Gest	Am. Potash & Chemical Co.	E
1950	Jan.	G. W. Sherman	Purdue University	S, E
	Jan.	P. R. Ewald	University of Tennessee	S, T, E
	Mar.	J. H. Cuthbert	Carnegie-Illinois Steel Co. (Gary Works)	T
	Mar.	Roy Johnson	Industrial Training Institute (Chicago)	S, T
	Apr.	R. L. Nichols	Magnolia Petroleum Co.	E
	June	J. B. Gray	Syracuse University	S
	July	E. P. Lambe & D. S. Duncan	Pratt Institute	S
1951	Feb.	J. H. Cuthbert	Carnegie-Illinois Steel Co. (Gary Works)	C, M
	Apr.	Wm. H. LaJoy	University of Minnesota (M.E. Dep't)	S

* Deceased. His successor is George Ehle

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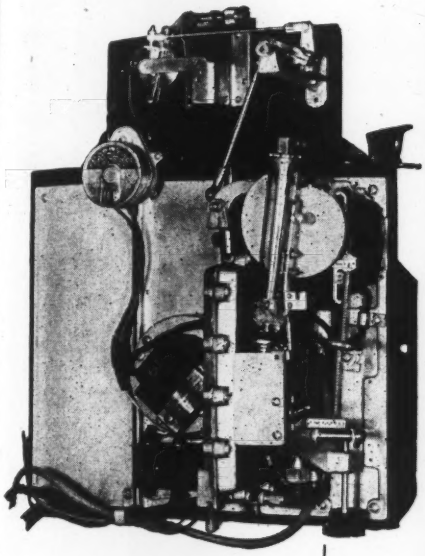
air flow

gas flow

or air flow-gas flow ratio



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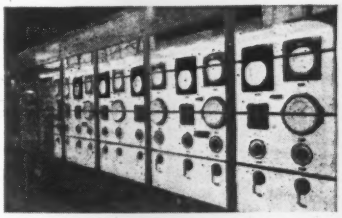
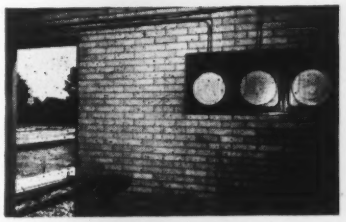


Industrial Furnaces—Diaflow measurement in open hearth, soaking pit, billet, slab heating and annealing furnace indicates excessive amounts of air and/or gas . . . helps to prevent fuel and gas waste . . . serves as a guide in maintaining product quality.



Sewage Disposal Plants—A guide to proper control of sewage treatment processes. Diaflow metering indicates: load on plant, variations in functions, relative rate of fluid flow and a continuing check on costs.

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Mention No. 601 when filling out card.

Ultrasonic Viscosimeter

New "Ultra-Viscoson" utilizes ultrasonic principle for continuous automatic viscosity measurement. Hermetically-sealed probe, fountain-pen size, has no moving parts, operates to 650 F., 10,000 atmospheres pressure, is installed permanently in pipe-lines, production kettles, or used in test tubes

and beakers. Electronic computer, located up to 1 mile from probe, indicates viscosity of Newtonian materials from 0-50,000 centipoises × grams/cc. in 4 decades: 0/50/500/5000/50000. Apparent viscosity of non-Newtonian materials measured over much greater range. Connection to recorder or controller provides continuous charts or automatic control.—*Rich-Roth Labs., 673 Connecticut Blvd., East Hartford* 8, *Conn.*

Mention No. 602 when filling out card.

X-Y Recorder

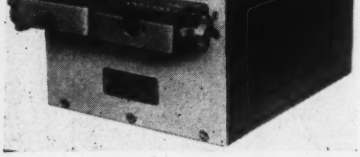
New "Autograf" records one variable as function of another on rectangular coordinates: speed-torque, stress-strain, E_G-I_P, frequency response, etc. Two

independent servo systems (powered from 115-v. 60-cps. line) position chart and pen, respectively, at a speed of 1 second for full-scale travel, with critical damping. Zero at either end on either axis, giving choice of all four quadrants. Accuracy and resolution within 0.25 percent. Scales 0-5 mv. to 0-100 volts. Weight 35 lbs. "Autograf" is fully-developed production model of 1948 NEC Exhibit instrument.—*Francis L. Moseley,* 1136 *No. Las Palmas Ave., Hollywood* 38, *Calif.*

Mention No. 603 when filling out card.

Analog Sampling Switch

New motor-driven sampling switch for zero drift correction of d-c. amplifiers in analog computers makes possible the use of one a-c. amplifier for

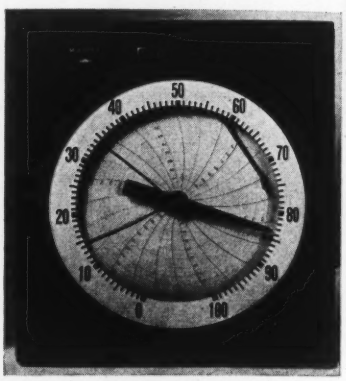


zero correction and gain improvement of as many as 30 d-c. computing amplifiers. Two poles; 60 contacts per pole; sampling rate 3.5 rps.; inter-contact resistance over 1,000 megs.—*Applied Science Corp. of Princeton, P. O. Box* 44, *Princeton, N. J.*

Mention No. 604 when filling out card.

Electropneumatic Receiver, Controller and Transmitter

New "ElectroniK Inductance Bridge Receiver" combines functions formerly requiring two instruments; makes it possible to indicate, record, integrate



and control flow and liquid level. Data can be retransmitted pneumatically to a second receiver remotely located. An "Indexet" mechanism is available to reset control index from a remote transmitter.—*Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia* 44, *Pa.*

Mention No. 605 when filling out card.

Dynamic Pressure Indicator

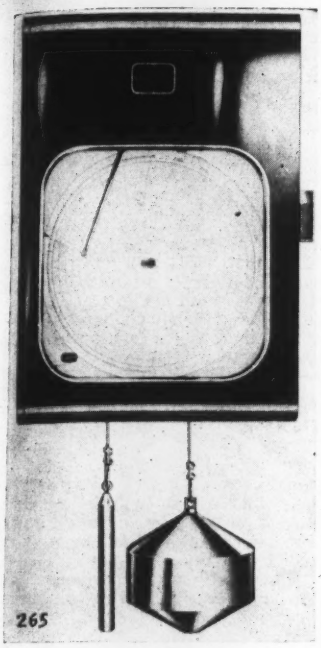
New "Model ST-12 Electronic Pick-up Indicator" measures transient, recurrent, and static pressures. Operation is based on phase-modulation principle using capacity-type pickup dia-

phragm with diameter of only 3/16 inch. Small diaphragm and carrier frequency of about 12.5 Mc. enable uniform response to high-frequency pressure transients. Weight 13 pounds. Multi-channel installations available for rack mounting. Up to 7 channels on standard 19-inch panel.—*Rutishauser Corp.,* 490 *So. Fair Oaks Ave., Pasadena* 1, *Calif.*

Mention No. 606 when filling out card.

Open-channel Flowmeters

New "Series 500" open-channel flowmeters (superseding "Model 40M") directly measure head of liquid flowing through a flume or over a weir; obtain flow-rate by means of a cam cut to

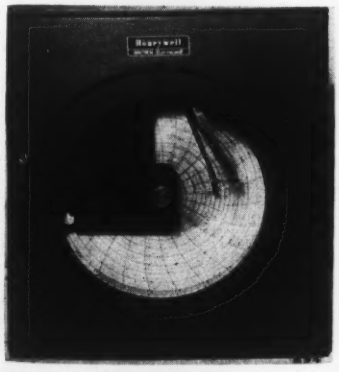


equation of weir or flume; indicate on a uniform chart; integrate if desired. Two types: mechanical, in which cam moves pen-arm across chart; electrical, employing maker's timed-impulse type of remote recording. Automatic control can be either air- or electric-operated. —*The Bristol Company, Waterbury* 20, *Conn.*

Mention No. 607 when filling out card.

Temperature-time Controller

New circular-chart temperature-time program controller utilizes a rotating plastic cam, cut to desired time-temperature pattern, and a cam fol-

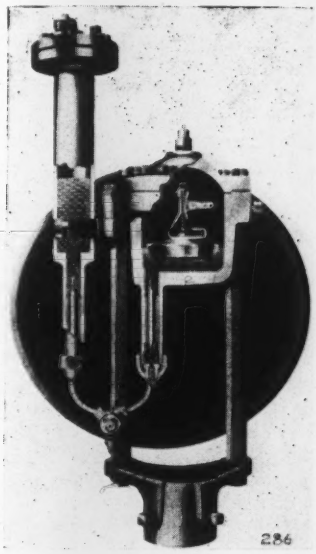


lower which actuates set-point index. Cam plate can be swung out without interfering with instrument action.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co.,* 4482 *Wayne Ave., Philadelphia* 44, *Pa.*

Mention No. 608 when filling out card.

Industrial Flowmeters

New models of maker's flowmeters embody five basic improvements: (1) pressure-seal bearing, factory lubricated, leak-proof at working pressures; (2) interchangeable plastic check floats

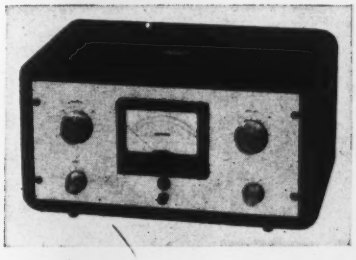


kept clean by complete submersion in mercury, and new stainless steel ball-plug and seat to prevent clogging and locking; (3) improved U-bend with metal-to-metal compression seals, and replaceable seats of hardened stainless steel; (4) new damping plug calibrated to simplify damping adjustments; (5) new type of stainless-steel ball-chain eliminates friction and errors of angularity.—*The Foxboro Company, Foxboro, Mass.*

Mention No. 609 when filling out card.

Micro-microammeter

New "Model V Micro-Microammeter" measures direct currents from 0.3 microampere to 0.3 micro-microampere full scale, with absolute accuracy bet-

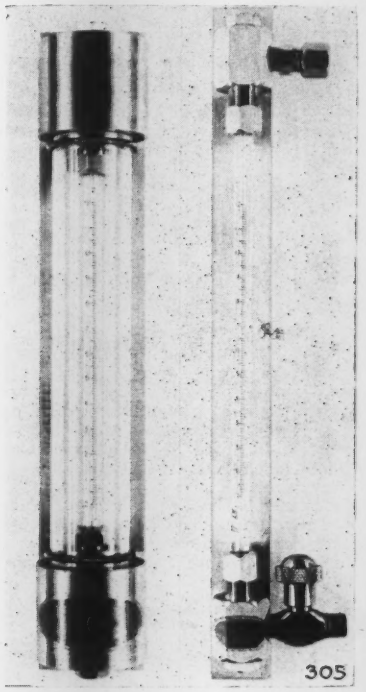


ter than 5 percent in all ranges. This results from vibrating-reed capacitor, used as capacitance modulator, housed in a hermetically sealed plug-in unit. Zero drift is typically less than 0.0005 volt in a 24-hour period; reproducibility of 1 percent is unaffected by ambient temperature or line voltage variations; currents as low as 3×10^{-15} amp. can be reliably detected.—*Beckman Instruments, Inc., South Pasadena* 5, *Calif.*

Mention No. 610 when filling out card.

Micro Flowmeters

New line of rotameters, for extremely accurate metering of small volumes of liquids and gases, fills a laboratory and bench-pilot-plant need because no equivalent instruments were commer-

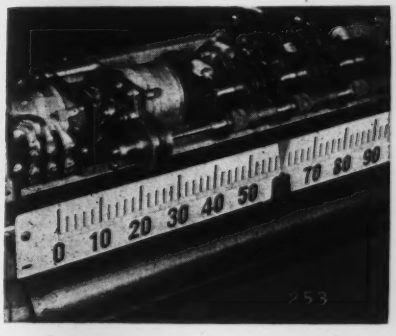


cially-available previously. Both high-pressure (1000 psig) and low-pressure (100 psig) models have maximum flow rates of 6-105 ml/min. for water and 90-610 ml/min. for air at 20 C. Four sizes of tubes are stocked. Tubes (replaceable in two minutes) have a fused-on solvent-proof millimeter scale. Plastic, aluminum, stainless steel, and gold floats are stocked; nickel and platinum floats can be supplied. An exclusive ionizing anti-static device can be installed on gas-metering tubes to completely eliminate erratic behavior of plastic floats used with gas flows.—*Technical Equipment Co.,* 4348 *San Pablo Ave., Emeryville* 8, *Calif.*

Mention No. 611 when filling out card.

Temperature-time Controller

New "ElectroniK" strip-chart recording and indicating program controller automatically maintains pre-set rates of temperature rise, fall, and



timed soaking or holding periods; can be supplied as a single- or multi-record electric-contact or proportional controller, or as a single-record pneumatic controller.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., 4482 Wayne Ave., Philadelphia 44, Pa.*

Mention No. 612 when filling out card.

Combustion Analyzer

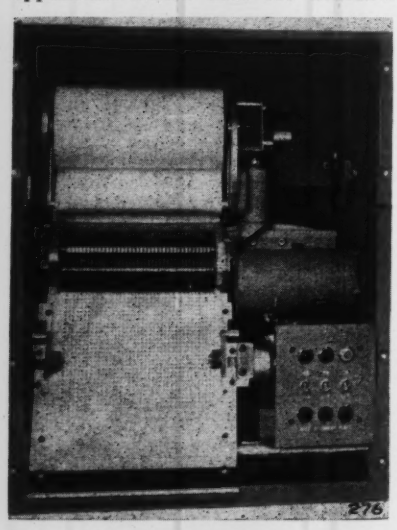
New "Model 140-A Veco" combustion analyzer indicates CO_2 content of flue gas, temperature of flue gas, and draft over fire. Features include glass-coated

thermistor and gas analysis cell with built-in temperature compensator. One probe is inserted into a small hole in flue to measure CO_2 content and stack temperature; other is inserted in front of furnace to measure draft over fire, permitting a series of readings to be taken without moving probes.—*Victory Engineering Corp., Springfield Road, Union, N. J.*

Mention No. 613 when filling out card.

Computer-data Printer

New "Synchroprinter" records output of analog or digital computers in directly-readable form on standard 8½-in.-wide paper; may be used in any application where data are available

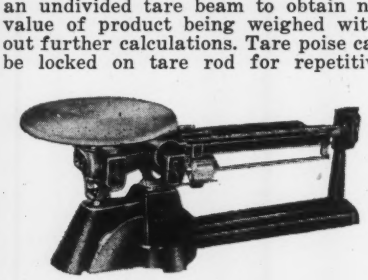


in electrical or mechanical form; can print fifteen lines of forty characters each in one second (600 characters per second). Independent control of printing and paper feed permits data produced at irregular time intervals to be consolidated into adjacent lines of print. Paper roll may be loaded in a few seconds.—*ANelex Corp., 53 State St., Boston 9, Mass.*

Mention No. 614 when filling out card.

Lab or Plant Balance

New "Triple Beam Balance" features an undivided tare beam to obtain net value of product being weighed without further calculations. Tare poise can be locked on tare rod for repetitive

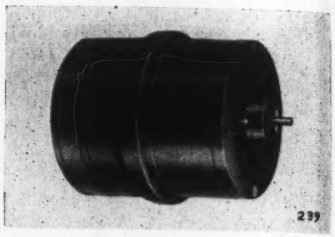


weighings. Full load capacity 2610 grams; sensitivity of 0.1 gram. Available in standard metric, avoirdupois, or troy. Different types of platforms, removable brass scoop or removable pan can be supplied.—*Ohaus Scale Corp., 1050 Commerce Ave., Union, N. J.*

Mention No. 615 when filling out card.

Drag-cup Type Generator

New rate generator (a-c. drag-cup tachometer) fabricated from non-corrosive materials, is designed for 60-cycle 115-volt operation, delivers 8.5



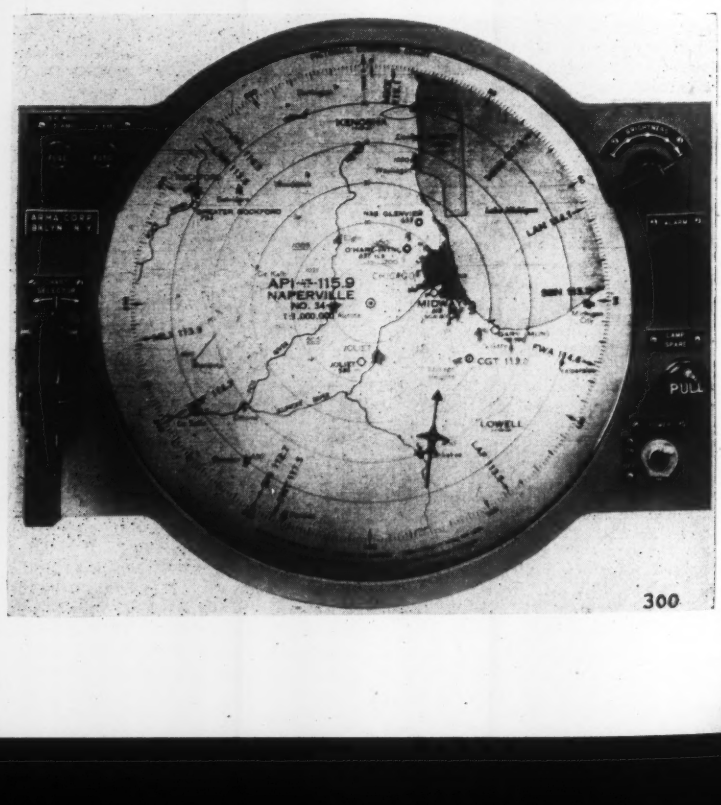
volts at 1000 rpm.; has a linearity of 0.1 percent to 1800 rpm. Zero speed residual (null) voltage is 100 millivolts, maximum. Weight, about 1 lb. —*Ford Instrument Co., Div., The Sperry Corp., 31-10 Thomson Ave., Long Island City 1, N. Y.*

Mention No. 616 when filling out card.

Pictorial Position Indicator for Airplanes

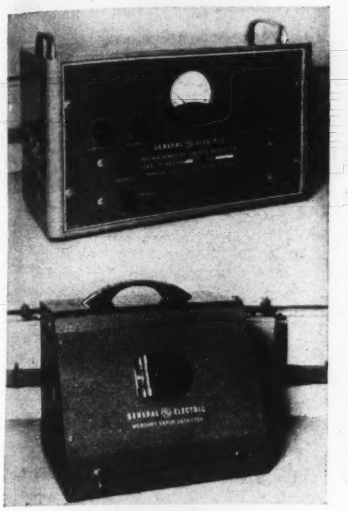
New "Pictorial Computer" automatically calculates an aircraft's distance and azimuth from a known point of radio transmission on ground. It mounts flush on instrument panel (within detail-seeing range of both pilot and co-pilot) and continuously displays, on a luminous screen, exact orientation of aircraft with respect to ground. Accuracies claimed are: range 0.4 mile at all scales, bearing 0.5 degree or 1/32 inch, and heading indicator 1 degree. Navigation with new instrument is based on Omni-Bearing Distance System and consists in selecting proper chart and keeping aircraft heading, corrected for crab angle, in line with route or destination. Each chart is part of a 35-mm. film roll, is projected at 10X onto a 10-in. see-through type screen. At center of chart is OBD station from which equipment computes range and bearing. Aircraft position is indicated on chart as center of a reticle of concentric range circles and radiating bearing lines. Aircraft heading is indicated on chart by a series of arrows passing through aircraft position and, in addition, by a symbolic aircraft outline. Charts are situated on film in a "route sequence" order, such as to minimize film movement required, particularly during flight. A chart selector motor, in conjunction with a variable-speed device, drives film roll at desired speed. "Pictorial Computer" is completely automatic except for selection of charts and for certain initial adjustments. Image brightness may be adjusted for operation under varying conditions from sunlight to darkness. Special charts will be prepared by U. S. Coast and Geodetic Survey in cooperation with CAA.—*Arma Corp., 254 36th St., Brooklyn, N. Y.*

Mention No. 617 when filling out card.



Mercury-vapor Detectors

New "Type A" (electronic) and "Type B" (chemical) portable mercury-vapor detectors indicate concentrations which could be harmful to industrial workers. Electronic instrument gives an instantaneous indication by resonant

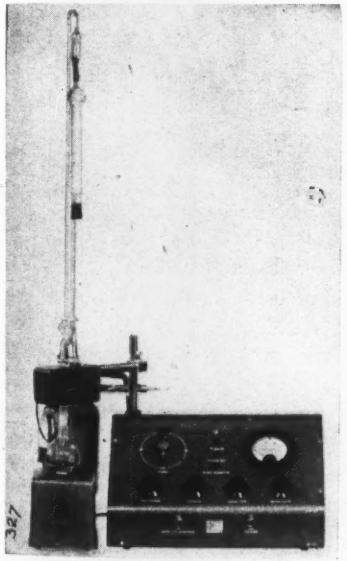


absorption of ultraviolet energy. Range 0.01 to 3.0 mg. Hg per cubic meter of air. Operational stability is independent of line voltage. Chemical detector utilizes darkening of activated selenium sulphide; is designed for continuous monitoring; will indicate as little as 0.1 mg. Hg per cubic meter of air in two hours.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 618 when filling out card.

Moisture Meter

New "Beckman Aquameter" permits moisture-content determinations to be made completely automatically. It uses Karl Fischer technique, thus eliminating errors caused by temperature effects, oxidation and decomposition. It



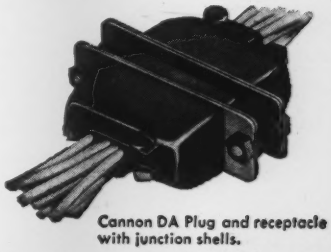
the new sub-miniature

CANNON PLUGS

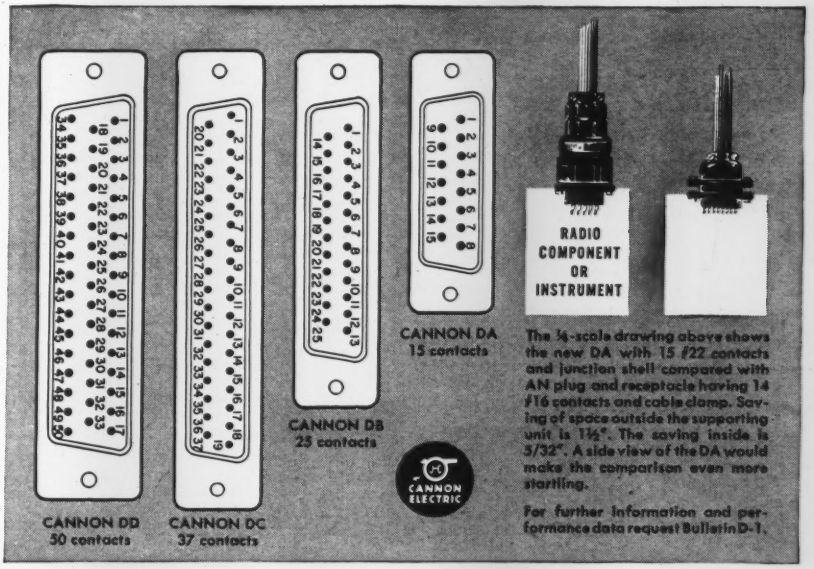
tiny but rugged

Series D Cannon Plugs satisfy a long felt need of the Electronics Industry for a sturdy, versatile and extremely compact connector for use on miniaturized equipment of all kinds. These may be mounted as (1) rack and panel (2) box (3) wall, or (4) cord connectors. Junction shells with integral clamps protect the terminal ends of the connector when used as cord or wall mounted units.

Contacts are of the quality you expect to find in any Cannon Plug. Machined from copper base alloy, gold plated, they accommodate #20 or #22 AWG stranded wire. Rated capacity 5 amps. High dielectric insulators. Minimum flashover, 1000 volts rms. The protective steel shells provide an integral mounting flange. The "keystone" shape of the shells gives positive polarization with friction type engagement.



Cannon DA Plug and receptacle with junction shells.



The ¼-scale drawing above shows the new DA with 15 #22 contacts and junction shell compared with AN plug and receptacle having 14 #16 contacts and cable clamp. Saving of space outside the supporting unit is 1½". The saving inside is 5/32". A side view of the DA would make the comparison even more startling.

For further information and performance data request Bulletin D-1.

CANNON ELECTRIC

SINCE 1915. Factories in Los Angeles, Toronto, New Haven, Benton Harbor. Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. F-180, P. O. Box 75, Lincoln Heights Station, Los Angeles 31, California.

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Tube Fitting Specialists—And Get The
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SWAGELOK FITTINGS AVAILABLE IN: BRASS, ALUMINUM, STEEL, STAINLESS STEEL, MONEL

COME TO YOU COMPLETELY ASSEMBLED, FINGER TIGHT

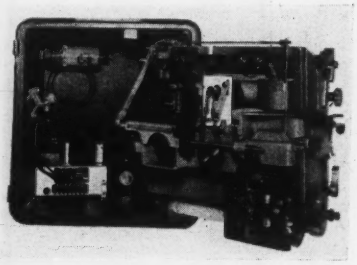
NEW INSTRUMENTS

consists of an electrically controlled titrating unit into which sample is introduced. A knob is then set and instrument completes titration automatically. Normally, one to two minutes are required.—*Beckman Instruments, Inc., South Pasadena, Calif.*

Mention No. 619 when filling out card.

Pyrometer Conversion Kit

New kit contains all parts necessary to convert a recording pyrometer from mechanical to electronic operation "by an inexperienced operator in four



hours," using a screwdriver, soldering iron, and pliers. Makers state: "Full-range scanning is possible in one and one-half seconds." Converter can be used in most well-known strip-chart and round-chart recorders and indicators.—*Pyrometer Service Co.*, 383 *River Rd., North Arlington, N. J.*

Mention No. 620 when filling out card.

Temperature Controller

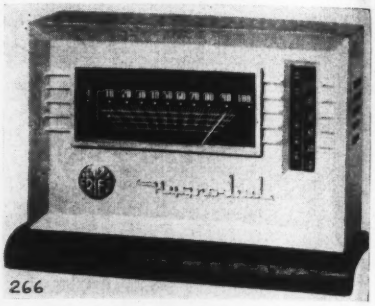
New "Pulse Pyr-O-Vane" millivoltmeter controller gives proportional on-to-off time-ratio cycles for temperature control of electrically-heated or fuel-fired furnaces, ovens, etc. Length of entire cycle is constant but can be selected from minimum of 3 sec. to maximum of 72 seconds by means of change-gears supplied with controller. Proportional band can be adjusted between 1 and 3 percent of full-scale. Signal lamps indicate on and off operation of control

relay. Relay contacts are rated 5 amps., may operate second relay on heavy-duty installations.—*Brown Instrument Div., Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.*

Mention No. 621 when filling out card.

Hygrometer

New "Model 186 Hygrodial" indicates relative humidity on a 2.5-in. scale uniformly graduated from 0 to 100 percent R.H. Measuring element is a multiple human-hair strand, 9

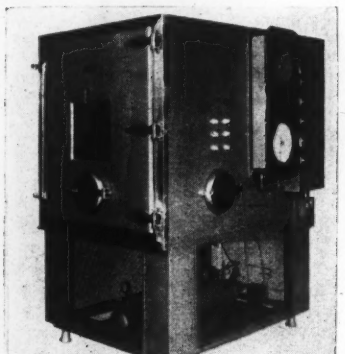


strands, 3 hairs per strand, total of 216 inches of fine blond hair (said to be more sensitive to humidity changes than brunette or red hair). A cam linearizes hairs' non-uniform extension. Temperature scale is 1.5 in. high; range 0 to 100 F.—*Abbeon Supply Co.*, 179-15 *Jamaica Ave., Jamaica* 32, *N. Y.*

Mention No. 622 when filling out card.

Humidity-test Cabinet

New 27-cu. ft. humidity testing cabinet will supply relative humidity between 20 and 95 percent in temperature range 35 F. to 185 F. Advantages over previous models are (1) faster temperature regulation throughout



range, and (2) elimination of damaging condensation (caused by changing temperatures during one test) through use of a high-capacity condensing system. Among standard features are a glass viewing panel with built-in wiper, two stainless-steel handhole ports, forced air circulation, adjustable shelf brackets in stainless steel working space, etc. Optional equipment includes a time schedule control system.—*Murphy & Miller*, 1326 *S. Michigan Ave., Chicago, Ill.*

Mention No. 623 when filling out card.

Grain-inspection X-ray Unit

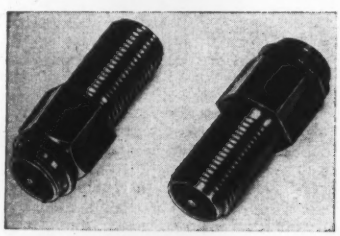
New "Grain Inspection X-ray unit" utilizes a new beryllium-window x-ray tube which allows for transmission of "soft" radiation required to examine low-density material such as grain.

(Until development of beryllium window, an x-ray grain inspection unit was impracticable.) Unit is shockproof, completely x-ray-shielded; operates at 25,000 volts and 5 ma. from ordinary 100/130-volt 60-cycle source; may be purchased outright, or furnished and maintained by maker under "Maxi-service" service-rental plan.—*X-ray Dep't, General Electric Co., 4855 Electric Ave., Milwaukee 14, Wis.*

Mention No. 624 when filling out card.

Contactless Motion and Displacement Pickup

New "Model 3010 Magnetic Pick-up" operates without physical contact when mounted near moving magnetic material; produces a voltage output proportional to speed of magnetic object;



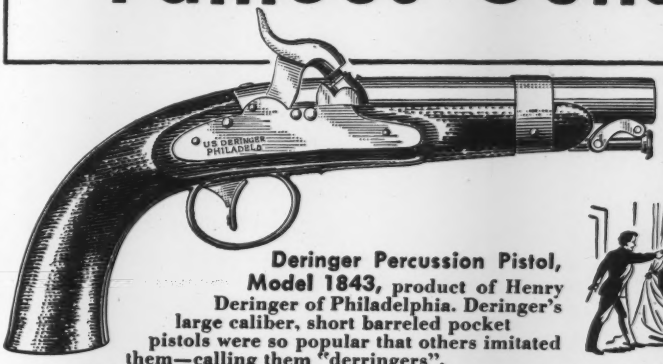
may be actuated by gear teeth, a screw head or pin on a moving part, etc., for measuring acceleration and velocity; triggering or synchronizing CRO sweep circuits; reference marker (degrees, position); counting strokes, etc. Output in excess of 2 volts peak to peak (depending on spacing, speed of moving part and displacement amplitude).—*Electro Products Laboratories, Inc., 4501 N. Ravenswood Ave., Chicago 40, Ill.*

Mention No. 625 when filling out card.

Magnetic Detector for Heat-corroded Weak Spots

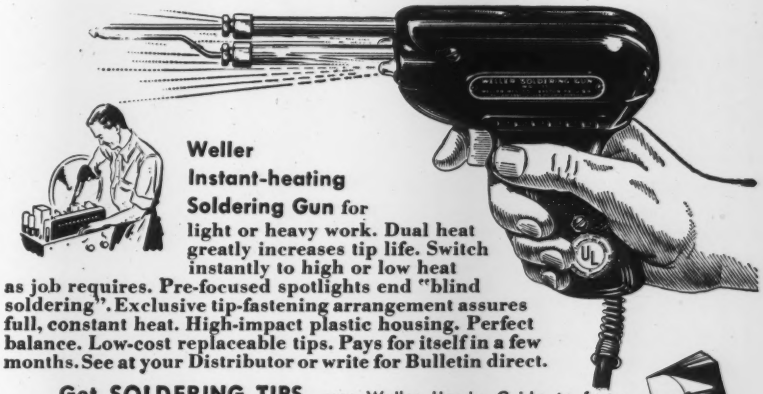
New "Magne-Probe" detects (non-destructively) weak spots due to heat corrosion in aircraft exhaust systems, etc., now being "tested" by means of a ball-peen hammer. It is based on discovery that changes caused by ex-

Famous Guns



Deringer Percussion Pistol, Model 1843, product of Henry Deringer of Philadelphia. Deringer's large caliber, short barreled pocket pistols were so popular that others imitated them—calling them "derringers". John Wilkes Booth used a Deringer to assassinate Lincoln.

Trap or Doorjamb Pistol, Caliber .31, made by North & Couch, Middletown, Conn. This lethal little device protected householders against burglars. Fixed to the doorjamb, with a cord running from muzzle rod to door, the pistol fired all its barrels into any intruder.



Weller Instant-heating Soldering Gun for light or heavy work. Dual heat greatly increases tip life. Switch instantly to high or low heat as job requires. Pre-focused spotlights end "blind soldering". Exclusive tip-fastening arrangement assures full, constant heat. High-impact plastic housing. Perfect balance. Low-cost replaceable tips. Pays for itself in a few months. See at your Distributor or write for Bulletin direct.

Get SOLDERING TIPS, new Weller Handy Guide to faster, easier soldering. 20 pages fully illustrated. Price 10c at your Distributor or order direct.

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SOLDERING GUNS 800 Packer Street, Easton, Pa.

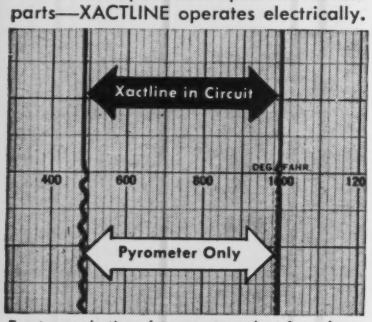
The Finest Soldering Tool for the Finest Craftsmen

Automatic
"STRAIGHT-LINE"
TEMPERATURE CONTROL
with
XACTLINE

ELIMINATE
Overshooting
Undershooting

Are you going to continue to put up with that troublesome overshooting and undershooting inherent in your conventional pyrometer control—especially when it is so easy to eliminate that saw-tooth effect?

Put XACTLINE in the control circuit. XACTLINE anticipates the temperature changes—before they occur. And too, it nullifies the varying amounts of thermal lag, residual heat, and mechanical lag—producing a short on-off cycle resulting in "Straight-Line" temperature control. This performance is possible because there is no dependence upon mechanical parts—XACTLINE operates electrically.



Exact reproduction of temperature chart for a heating process showing the comparison of the "Straight-Line" temperature control produced by XACTLINE and the saw-tooth curve obtained with only conventional control.

XACTLINE is applicable to any indicating or recording pyrometer control of the millivoltmeter or potentiometer type. It should be used wherever close temperature control is required—any type of electrically heated oven, furnace, kiln, injection molding machine, and fuel-fired furnaces equipped with motor-operated or solenoid valves.

XACTLINE is a complete unit. No adjustment or coordination with the control instrument is required regardless of the size of the furnace, length of the heating cycle, or size of the load. Installation is very simple—can be either flush or surface mounted.

PRICE $89.50 F.O.B. CHICAGO
Nothing else to Buy

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CLAUD S. GORDON CO.
Manufacturers & Distributors
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Dept. 21 • 3000 South Wallace St., Chicago 16, Ill.
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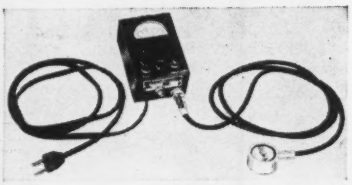
NEW INSTRUMENTS

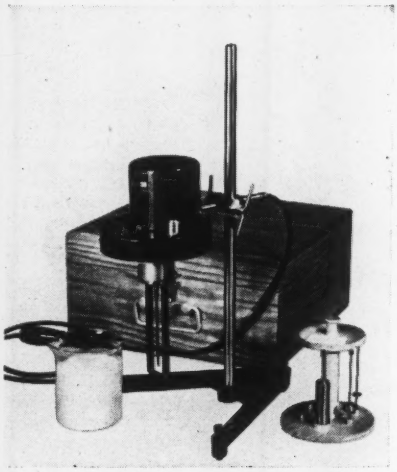


haust-gas heat increase magnetic permeability of Inconel, stainless-steel, etc. Principle of detection: structure being tested forms "core" of coil in probe; inductance is proportional to permeability of "core" material; instrument's bridge circuit measures inductance.—*American Instrument Co., 8030 Georgia Ave., Silver Spring, Md.*

Mention No. 626 when filling out card.

Viscosimeters

New models of "Synchro-Lectric Viscometers" are announced. Illustrated is eight-speed "Model LVT" with 200-to-1 ratio of speeds starting at 0.3



rpm. When equipped with "UL Adapter," it can measure any viscosity between 0.5 and 2,000,000 centipoises. There is also a new modified four-speed model, and 10 other single- and four-speed models. Any standard model now may be secured with explosion-proof construction. Each new 1952 viscometer is accompanied by a complete set of suitable spindles, spindle holder, and carrying case.—*Brookfield Engineering Labs, Inc., Porter St., Stoughton, Mass.*

Mention No. 627 when filling out card.

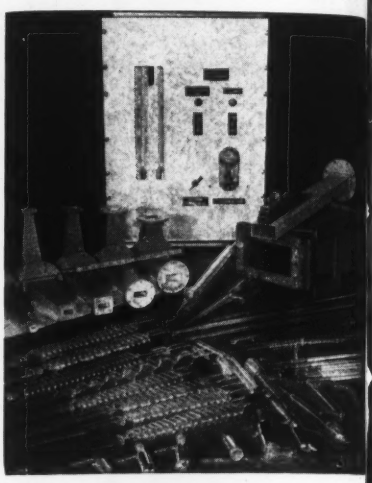
U-tube Manometer

New "Type B" straight-tube U-tube manometer is available in lengths from 10 to 100 inches and with graduations in inches, tenths, or quarters of water or mercury, or in any other equivalent units such as pounds, ounces, millimeters, grams, etc.—*Uehling Instrument Co., 473 Getty Ave., Paterson, N. J.*

Mention No. 628 when filling out card.

Wave-Guide Calorimeter

New Microwave Calorimeter for absolute measurement of microwave or radar power is said to have "a degree of accuracy never before possible with commercial instruments." It circulates measured amounts of water through a glass water load in

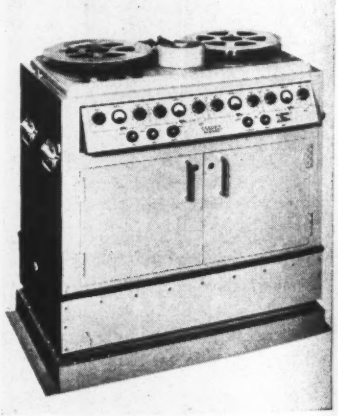


a wave-guide coupled to a microwave power source; measures incoming and returning water temperature difference. Water load completely absorbs microwave power so that calories per minute (flow-rate in cc/min. times temperature rise in C. deg.) divided by 14.334, give watts, accurate to better than 1 percent for most measurement ranges. Units in production are capable of measuring between 250 milliwatts and 10,000 watts average power on frequencies between 100 and 30,000 Mc.—*Transport Products Corp., Gillespie Airport, Santee, Calif.*

Mention No. 629 when filling out card.

Magnetic-tape Recorder

New "Model 500" multi-track magnetic tape recorder meets standards of high-frequency telemetering and applications in guided missiles, computers, etc. It reproduces 100 to 100,000 cps. with "lowest possible flutter and wow accomplished in recording field," with less than 0.1 percent peak-to-peak limit. New drive system is said to accomplish more than 5-to-1 improve-

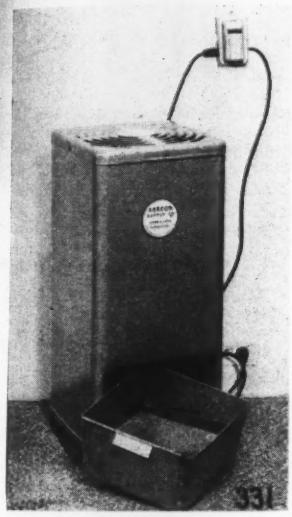


ment over best previous recorders. Signal-to-noise ratio is over 40 db below 1 percent harmonic distortion when measured in 15-percent band widths. "Speed-Lock" assures that recorded frequencies are played back as originally recorded, regardless of tape dimensional changes, power line frequency variations or tape slippage. Tape capacity up to 5000 feet on 14-in. reels, providing a playing time of 16 min. at 60 ips. or 32 min. at 30 ips. Four individual track records.—*Ampex Electric Corp., Redwood City, Calif.*

Mention No. 630 when filling out card.

Dehumidifier

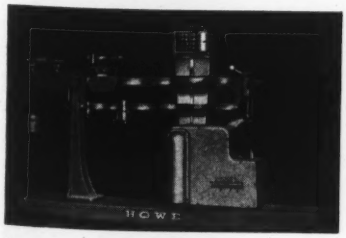
New "Model WA-5" dehumidifier will dehumidify about 13,500 cubic feet in average basement (larger volume if conditions are less severe); is available without automatic control, with separate automatic controller (illustrated), and with built-in controller. Maker's volume production of industrial units is said to make price low enough for a large shop to install a number of units.—*Abbeon Supply Co., 179-15 Jamaica Ave., Jamaica, N. Y.*



Mention No. 631 when filling out card.

Projector-type Weight Indicator for Scales

New "No. 77 Weightograph Unit" features a new projection type of weight indication; can be attached to any make of beam scale, or to any scale convertible to beam operation. Unit has a non-protruding periscope with an eye-level screen which flashes weight in large, illuminated figures. Projection method is said to increase image bright-



Who's Kidding Who?

YOU'RE kidding YOURSELF if you think every safety valve is equally safe.

We know of one case where inspection showed that 27 out of 36 safety valves were stuck tight—*would not have operated at pressures far above the set point*—yet the user of those valves *thought* he had protection. He *could* have been stuck right along with those 27 valves.

If you want 100 per cent safety—and you'd hardly want less—there's one sure way to get it—specify BalanSeal or FarriSeal Safety Valves.

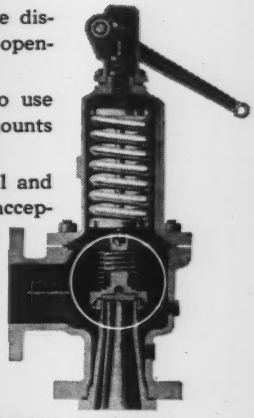
Why? Because they *can't* stick, plug or corrode. Critical working parts are permanently isolated from any contact whatever with the lading.

Because they're unaffected by back pressures in the discharge manifold due to its own operation or to the opening of other valves in the line.

Because these features make it possible for you to use smaller discharge piping, an economy which often amounts to substantially more than the cost of the valves.

You'll be interested in the engineering of BalanSeal and FarriSeal Valves—design which is rapidly gaining acceptance in hundreds of successful installations.

Ask for our "8-Minute Brief."



1189 R

Your Safety's REAL With FarriSeal

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436 COMMERCIAL AVE., PALISADES PARK, N. J.

AFFILIATES

Farris Stacon Corp. *Temperature Regulators* • Farris Flexible Valve Corp. *Pinch Type*
Farris Hydrotorque Corp. *Remote Controls* • Farris Hydroseal Corp. *Elastic Piston Seals*

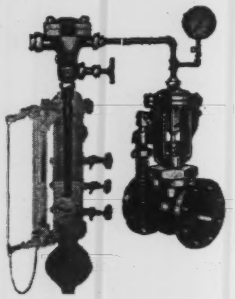
IN LOUISIANA

An ATLAS representative writes as follows about boiler troubles in a Louisiana sawmill. After solving the difficulties he says:

"Each boiler was supplied with a

CAMPBELL
Boiler Feed Water Regulator

—in which no floats, thermostats, or generators were involved in the design or construction. A continuous blowdown feature was incorporated in the unit."



He concludes:
"The plant now has ample dry steam, with more excess fuel than can be burned under the boilers."

Users of the CAMPBELL Like These Six Points:

1—Continuous Blowdown;

2—No Moving Parts;

3—No Thermostats;

4—No Floats

5—No Links;

6—No Generators.

The CAMPBELL has been controlling all types and sizes of boilers for many years—SUCCESSFULLY. Note the INDICATING GAGE (shown above) which can be placed on the switchboard or control board, showing what the regulator is doing at all times.

Slightest changes in water level cause the CAMPBELL to operate the largest control valves instantly. Rugged. Efficient. Economical. No fine adjustments. Easy to install. 50 to 400 lb. pressure and up.

Sizes 1" to 6". Guaranteed by a concern that has been in the regulating valve business EXCLUSIVELY for more than a half century.

Using the coupon below will save time

ATLAS VALVE COMPANY
REGULATING VALVES FOR EVERY SERVICE

292 SOUTH ST., NEWARK 5, N. J.

Represented in Principal Cities

☐ Without obligation, please send data on the CAMPBELL Boiler Feedwater Regulator. Also, please send complete information on the following ATLAS products:

☐ Damper Regulators	☐ Oil Control Cocks
☐ Temperature Regulators	☐ Humidity Controllers
☐ Exhaust Control Systems	☐ Thermostats
☐ Pressure Regulators	☐ Balanced Valves
☐ Pump Governors	☐ Control Valves

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NEW INSTRUMENTS

ness and contrast five times. Reading line length is 180 inches. Unit can also be used for "over" and "under" readings.—*The Howe Scale Co., Rutland, Vermont.*

Mention No. 632 when filling out card.

Indicating Pyrometer

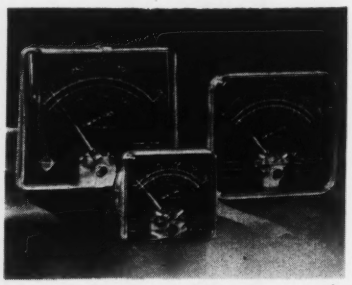
New "No. 327-T" pocket-size millivoltmeter is calibrated for its associ-

ated thermocouple and for a 1/16-in. steel panel. Graduations to 2250 F. and to 1250 C.—*L & L Mfg. Co.*, 804 *Mulberry St., Upland, Chester, Penna.*

Mention No. 633 when filling out card.

Indicating Pyrometers

New "Black Face Pyrometers," clear plastic case instruments with black dial faces, are made in three sizes (2.5, 3.75 and 4.5 in.) and nine standard



temperature ranges from −200 to 3000 F.; corresponding C. shown. All incorporate quality features of maker's "Simplytrol Pyrometers."—*Assembly Products, Inc., Chagrin Falls, Ohio.*

Mention No. 634 when filling out card.

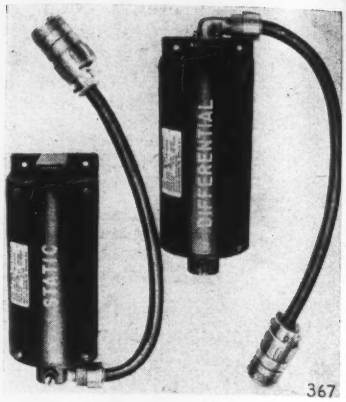
Thermocouple Insulators

New thermocouple insulators are made of new "Thermo Body" and therefore withstand thermal shock better than those made of older material. They are available in more than 300 shapes and sizes.—*Dep't* 17, *Saxonburg Potteries, Saxonburg, Penna.*

Mention No. 635 when filling out card.

Pressure Pickups

New "TR 101" static and "TR 102" differential pressure pickups are of electromagnetic type comprising a variable-reluctance 400-cps. bridge circuit and a cantilever-suspended Bourdon

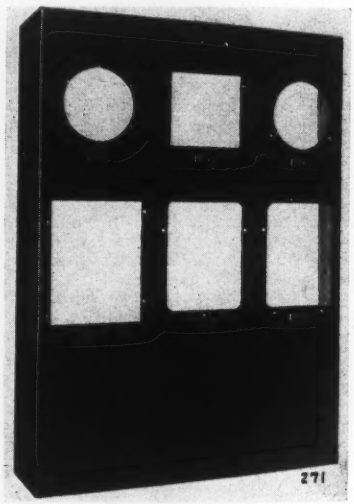


tube. Among features: (1) No bearing or sliding contacts; (2) Bourdon tube constructed of zero thermoelastic coefficient material; (3) thermostatically controlled heaters to ensure reliability over wide temperature ranges; (4) meet requirements of AN-E-19; (5) construction eliminates detrimental effects of vibration. Pressure ranges under 15 psi.; outputs 0 to about 3 volts.—*Servomechanisms Inc., Westbury, L.I., N. Y.*

Mention No. 636 when filling out card.

Self-supporting Panelboard

New "Deep Wing Panel" is made of completely formed steel, with 2-in. return edges at top and bottom and side

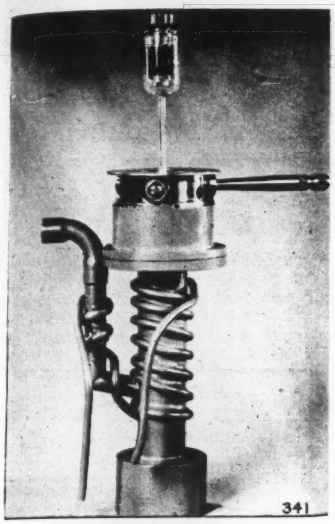


wings from 12 in. to 18 in. or wider. These wings serve as support members; can also be used to mount terminal blocks and other electrical or mechanical equipment.—*Falstrom Co., Falstrom Court, Passaic, N. J.*

Mention No. 637 when filling out card.

High-vacuum Pumping Unit

New "MB-10 Pump, Valve and Port Assembly" is a high-vacuum conversion pumping unit of large capacity, for use with conventional rotary exhaust machines and designed specifically to evacuate standard electron tubes; can also be used to pump hermetically-sealed

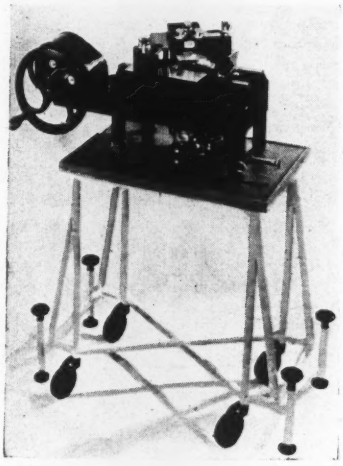


relays, vials, instrument control elements, etc. Pumping speed 10 liters/sec. between 0.1 and 10.0 microns; ultimate vacuum 0.05 micron. Jet assembly of special design easily disassembled for cleaning. — *Distillation Products Industries Div. of Eastman Kodak Co., Rochester 3, N. Y.*

Mention No. 638 when filling out card.

Microtome

New "Model K" microtome, designed for sectioning hardest objects, makes it possible to cut plastics, etc., into extremely thin (about 4 microns) foils



for microscopic observation in transmitted light. Hardest tropical wood can be cut without boiling. Metals such as copper can be cut into sections a few microns thick. A freezing chamber for cutting elastic materials is fastened onto object-clamp.—*William J. Hacker & Co., Inc., 82 Beaver St., New York 5, N. Y.*

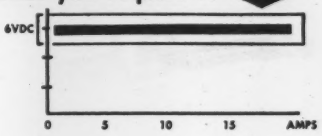
Mention No. 639 when filling out card.

Hot Bench

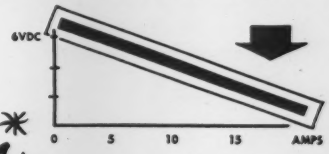
New "Lo-temp" hot bench supplements "Standard" hot bench, has temperature range from 10 to 230 C. for

Problem •

What you require is



Your present DC source gives you



Solution • nobatron*

Sorensen NOBATRONS provide regulated DC voltage, stabilized against LOAD changes as well as LINE fluctuations. A wide range of standard models are available in capacities from 7 to 200 VDC, 5 to 350 amps.

COMMON NOBATRON SPECIFICATIONS

Input Voltage range	95-130 VAC, single ϕ, 50-60 ~ High-current units 208/115, 3ϕ, 4-wire, wye.
Output voltage range	Adjustable ± 10% with rated accuracy, — 25% with lesser accuracy.
Regulation accuracy	± 0.2% from 1/10 to full load.
Ripple voltage	1% RMS. Time constant 0.2 seconds.

*Reg. U. S. Pat. Off. by Sorensen & Co., Inc.

Model E-6-15

SR-10

for maximum Flexibility the nobatron Ranger

Nobatron-RANGERS are continuously adjustable over wide output ranges, yet provide regulation accuracy of ± 0.25%. Other specifications are identical to those of the standard NOBATRONS.

Standard models with adjustable outputs of 3-30VDC, 3-135VDC, 200-300VDC.

Write for full information on Nobatrons, Nobatron-Rangers, and other Sorensen Isotronic† products.

†Isotronic is a trade-marked word pertaining to the electronic regulation and control of voltage, current, power, or frequency.

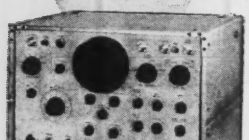
Specify SORENSEN

Sorensen & Company, Inc. • 375 Fairfield Ave., Stamford, Conn.

THE LAB PULSESCOPE

BY WATERMAN

MODEL S-5-A



Weight 60 lbs.
13" x 16" x 14"

Another Waterman first, a compact, portable wide band pass laboratory oscilloscope with markers that are triggered in synchronism with the incoming signal. Ideal for pulse measurements, such as shape, amplitude, duration and time displacement. S-5-A LAB PULSESCOPE is adaptable to all kinds of electronic work where knowledge of circuit performance is essential. Built in Video delay permits observation of leading edge of triggering pulse. Precision means of amplitude calibration are provided. Sweep can be either repetitive or trigger with 10 to 1 expansion when desired. Internally generated markers, together with Video calibration, provide quantitative data of amplitude, shape, duration and time displacement of pulses. The oscilloscope thus is truly a PULSESCOPE, another Waterman first.

Video amplifier up to 11 mc . . . Video Delay 0.55 μs . . . Pulse rise and fall time better than 0.1 μs . . . Video sensitivity 0.1v p to p/in. . . . Sweep 1.2 μs to 120,000 μs with 10 to 1 sweep expansion . . . Sweep triggered or repetitive . . . Internal markers synchronized with sweep from 0.2 μs to 500 μs . . . Trigger generator with output available externally . . . Built in precision amplitude calibrator . . . Combination case . . . Operates on 50 to 1000 cycles at 115V AC.

WATERMAN PRODUCTS CO., INC.

PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

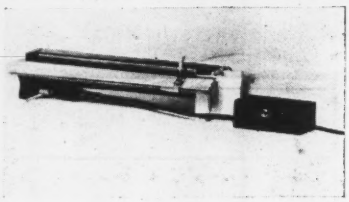
WATERMAN PRODUCTS INCLUDE:

S-4-A SAR	PULSESCOPE
S-10-B GENERAL	POCKETSCOPE
S-11-A INDUSTRIAL	POCKETSCOPE
S-14-A HIGH GAIN	POCKETSCOPE
S-14-B WIDE BAND	POCKETSCOPE
S-15-A TWIN TUBE	POCKETSCOPE

Also RAKSCOPES, RAYONIC
Cathode Ray Tubes
and other equipment

WATERMAN PRODUCTS

NEW INSTRUMENTS

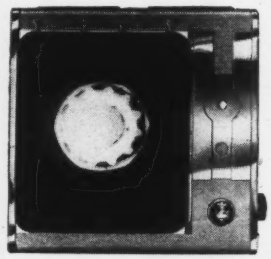


determination of melting-points of waxes, fats, etc. Accuracy is 1 C. Specimen is laid directly on chrome-plated surface of electrically-heated "body." Made by C. Reichert Optical Works, Vienna. Deliveries from May 1952.—*William J. Hacker & Co., 82 Beaver St., New York 5, N. Y.*

Mention No. 640 when filling out card.

X-ray Film Illuminator

New "High Intensity Illuminator" is said to make x-ray film inspection of industrial parts quick, easy and accurate, light intensity being twenty times that of conventional viewers. Full viewing surface is 14 x 17 in.; and critical examination of small areas is accomplished before a 3-in. spot of



four times over-all intensity, permitting evaluation of details in films exceeding 4.5 density. Also separate masks for small films viewed on large area. Cool front allows extended viewing without curling film. Accessories include clips and drip pan for wet film examination.—*Keleket X-ray Corp., 225 W. Fourth St., Covington, Ky.*

Mention No. 641 when filling out card.

Hand Sugar Refractometer

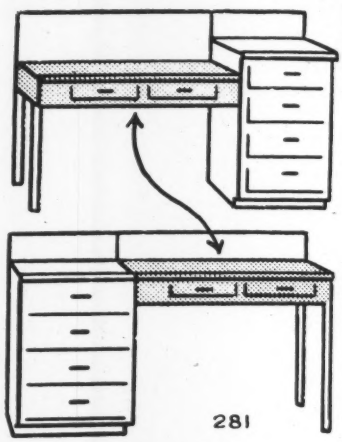
New "Opton Hand Sugar Refractometer" for rapid examination of fruit juices, either in field or during processing, embodies improvements over form-

er equipment: range has been increased to 0-85 percent dry substance, which formerly required two instruments. New refractometer has two scales: 0-55 percent and 55-85 percent, brought into view by turning a knob. Measurements may be made in transmitted or reflected light. Sharply-defined line of total reflection is seen through eye-piece. Dry substance can be estimated to 0.2 percent. Built-in thermometer is insulated against heat of user's hand. Refractometer is made in U. S. Zone of Germany.—*Carl Zeiss, Inc., 485 Fifth Ave., New York 17, N. Y.*

Mention No. 642 when filling out card.

Lab Table Unit

New "Versa-Table" furniture unit, added to maker's "Unitized Furniture," will meet any laboratory's need for 30 x 48 inches of additional and unobstructed working space. Eight differ-



ent methods of installation are possible (two illustrated here). Steel upper section can be topped with stainless steel, Kemrock, or Formica bonded to heavy plywood sections; also a stainless-steel top with integral splashback and reagent shelf, legs in two heights, etc.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 643 when filling out card.

Chromatography Unit

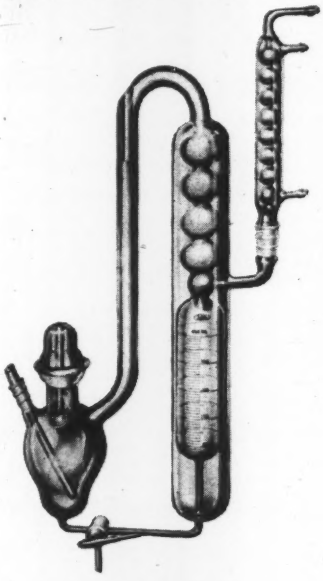
New standardized chromatography apparatus includes a stainless-steel support rack to hold strips; a glass tray and Petri dish for solvent; glass rods for attaching and holding strips. Apparatus fits into a Pyrex glass jar 12 in. o.d. and 24 in. high; closure makes possible saturated atmosphere

required for optimum analyses: glass cover plate has a stoppered half-inch hole in center for adding solvent without lifting entire top and disrupting atmosphere's equilibrium.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 644 when filling out card.

Vaporization Still

New flash vaporization equilibrium still is said to obtain equilibrium flash vaporization data for petroleum mixtures as easily as determining ordinary boiling-point data. It always obtains true equilibrium, normally not obtainable in continuously-operated pilot-plant equipment. Small quantity

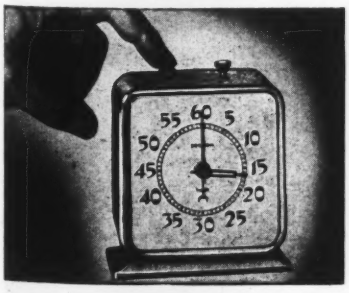


of charge material is required per determination: 500 to 2000 ml. per flash curve as compared with about two barrels for continuous type. Negligible pressure drop through unit permits reading pressure at a point where condensing vapors do not clog manometer. —*Emil Greiner Co., 20-26 N. Moore St., New York 13, N. Y.*

Mention No. 645 when filling out card.

Stop-clock

New "Secron" stop-clock combines accuracy of a stopwatch with across-the-room visibility of a household clock; has a 36-hour movement controlled by two buttons on top: green for start, red for stop. Reset knob is on back. Sweep hand permits estimations to



Product of
Marsh Instrument Co.,
Skokie, Illinois

The Marsh Pocket Thermometer, dial type, is an all-purpose instrument with the ruggedness to "take it". With an unbreakable crystal, it's easy to read, accurate and nicely styled in a handsome case of heavy gauge stainless steel. The steel clip makes a convenient hanger or pocket clasp. Its uses are varied—such as in servicing commercial refrigerators, quick freezers, air-conditioning and heating plants and others. And it's mighty handy for instant, safe readings in your own home freezer, in your car—anywhere. Of course, its reliability is largely dependent upon the actuating element of Chace Thermostatic Bimetal.

A small precision-wound coil is fixed to one end of the indicator shaft, the outer end being hooked into a bracket on the back of the dial. Changes in temperature cause the element to coil or un-coil, thus rotating the indicating pointer to the correct temperature reading. The indicator may be calibrated with considerable accuracy by sliding the bracket to right or left.

Chace Thermostatic Bimetal is manufactured in 29 types, in strips, random coiled lengths or in completely fabricated elements of customers' design. We also provide the specialized tooling required for fabrication and are qualified to produce welded and brazed sub-assemblies. Before proceeding with your next design, consult our Applications Engineers or write for our new 32-page booklet, "Successful Applications of Chace Thermostatic Bimetal" containing condensed engineering data.

IT BENDS WITH THE HEAT

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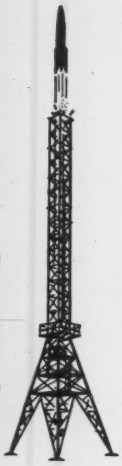

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NEW INSTRUMENTS

half a second; smaller integrating hand registers elapsed time to 60 minutes. Case size 4 by 4.5 in. Immediate delivery.—*Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.*

Mention No. 646 when filling out card.

Electric Stirrer

New "No. 601 Portable Electric Reciprocating Stirrer" operates on 110-v. 60-cy. a.c.; has motor speed of 120 rpm. (others on request); provides adjustable 1-in.; 1.5-in. and 2-in. stroke

lengths; is especially suitable for small-diameter vessels in molecular-weight determinations, in obtaining cooling-curves, etc.—*Research Appliance Co., Box 413, West View Road, Pittsburgh 9, Penna.*

Mention No. 647 when filling out card.

Laboratory Stirrer

New "Versatile Stirrer" is said to do "what formerly required at least three different stirrers." Three shafts (two geared to rotor shaft) provide max.-

speeds of 140, 825 and 5,000 rpm. respectively; intermediate speeds (from "off") by rheostat. Clutch-type clamp makes it easy to swing from one position to another. Chuck will take rods up to 5/16 in. diameter. Enclosed motor runs on d.c. or a.c.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 648 when filling out card.

Compression Tester

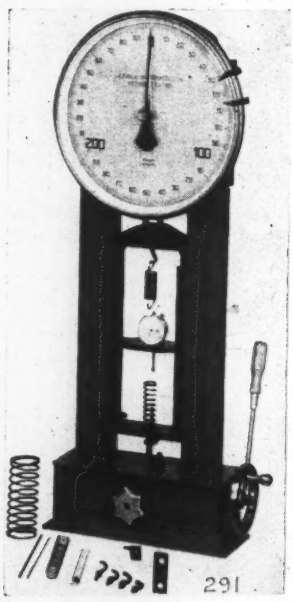
New "Multi-purpose Compression Tester," originally designed for "flat crush" tests of boxboard, can be used also to test a wide variety materials

and finished products. Accuracy 0.5 percent at half-capacity and above, one scale division (0.5 lb.) at lower loadings. Dual load range: 0-100 lbs. and 0-1000 lbs. Tester handles specimens up to 12 x 12 in. by 16 in. high.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.*

Mention No. 649 when filling out card.

Spring Tester

New "Carlson-Chatillon Spring Tester" for checking loads and deflections of compression and extension springs can be used for both general purpose testing and for high quantity produc-



tion testing at 300 to 600 tests per hour. Production stops and tolerance markers are adjustable and 0.25 percent accuracy is guaranteed, meeting requirements of National Bureau of Standards. Capacity—loads up 300 lbs.; spring diameters up to 4 in.; spring lengths up to 12 in. for compression and 10 in. for extension.—*The Carlson Company, 277 Broadway, New York 7, N. Y.*

Mention No. 650 when filling out card.

Magnetic Probe

New "G-S Magnetic Probe," made of super-magnetic alloy, is fountain-pen size. Point of magnet is extended or retracted by turning end-knob. This

controls strength. Uses: removing steel or iron particles from electrical instruments, etc.; testing coat of surfaces for magnetic properties of undermaterial; removing steel splinters from eyes or skin. Probe can be sterilized without harming magnet. — *General Scientific Equipment Co., 2700 W. Huntingdon Street, Philadelphia 32, Penna.*

Mention No. 651 when filling out card.

Running-time Meter

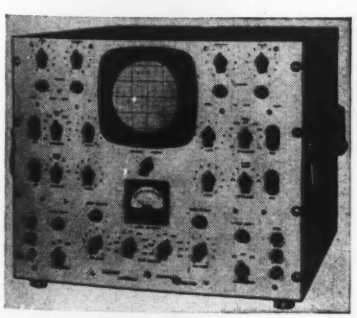
New running-time meter is hermetically-sealed and tamper-proof. Tempered-glass crystal is fused directly to steel case. Self-starting synchronous

motor, 110-125, 220-250 volts, 50 or 60 cps. Meter registers in 1/10-hour steps to 9999.9, or hour steps to 99999.— *Marion Electrical Instrument Co., 401 Canal St., Manchester, N. H.*

Mention No. 652 when filling out card.

Dual-channel Oscilloscope

New "Model H-21A" general-purpose twin channel oscilloscope, displaying two independent signals on the face of a single 5-in. cathode-ray tube, is designed for either cabinet or relay rack mounting. Each channel has indi-



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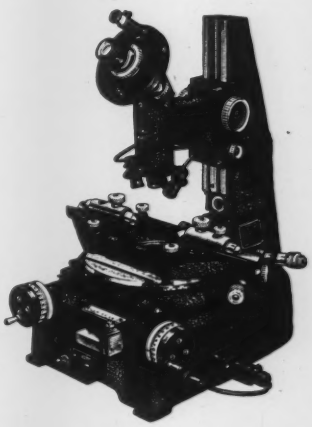
For use wherever precision measurements are required in shop inspection or layout procedures.



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Left to Right	100 mm or 4 inches
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Stage Range	360°
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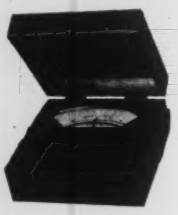

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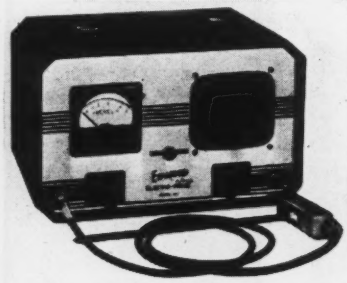
NEW INSTRUMENTS

vidual controls for intensity, focus and positioning of the *X* and *Y* axes. Both input signals can be observed either on a common time base or on separate time bases. Exceptionally stable sweep circuits (range 2 cps. to 50 kc.) can be triggered with a delay of less than one microsecond. Transfer switch permitting interchange of axes adapts instrument for photographic recording with vertical-film-motion cameras. Built-in 60-cps. square wave to either vertical amplifier.—*Electronic Tube Corp., 1200 East Mermaid Lane, Phila. 18, Penna.*

Mention No. 653 when filling out card.

Electronic Trouble Spotter

New "Electro-Probe," for locating and analyzing source of noises and vibrations in mechanical devices while they are in operation, comprises a vibration pick-up probe and 3-stage

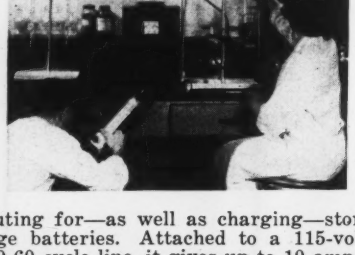


amplifier; speaker and headphones to provide audible comparison of vibration sounds within range of 60 db., and calibrated instrument for visual indication. Unit operates on 110-120-volt 60-cps. a.c., consumes 36 watts; weighs 14 lbs. Complete instructions supplied; no special training or skill required.—*Erwood, Inc., 1770 Berteau St., Chicago 13, Ill.*

Mention No. 654 when filling out card.

Laboratory Power Supply

New "Powerhouse" supplies variable, controlled power for electroplating, electropolishing and electroanalysis; energizing electromagnets; and substi-

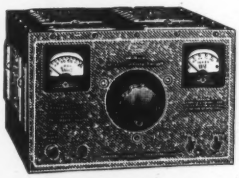


tuting for—as well as charging—storage batteries. Attached to a 115-volt 50-60 cycle line, it gives up to 10 amps. at 10 v.; also variable a-c. output of 0-130 volts with maximum of 3 amps.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 655 when filling out card.

D-c. Power Supply

New "Model NF Universal D-c. Power Supply" has less than 1 percent ripple or hum at top load. Output 0 to 28 volts up to 15 amps and 0 to 36 volts

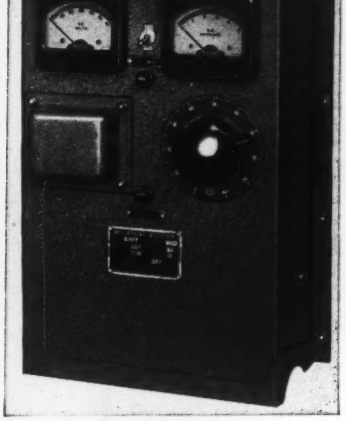


up to 6 amps. continuous duty; to 25 amps. intermittent.—*Electro Products Laboratories, Inc., 4501 N. Ravenswood Ave., Chicago 40, Ill.*

Mention No. 656 when filling out card.

D-c. and A-c. Supply

New "R-P-3 Science Panel" rectifier is primarily designed for instruction and demonstration, is said to have a multitude of opportunities to serve in-

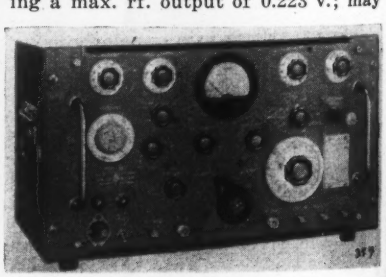


dustry. Announcement states: "It has the happy quality of serving up a.c. or d.c. current, operating on 0 to 28 volts, 10 amps. Meeting the demand for a.c. or d.c. is merely throwing a small switch."—*Electronic Rectifier Co., Rochester, N. Y.*

Mention No. 657 when filling out card.

Test Sets for SHF

New "Model 624A SHF" test set offers continuous frequency coverage over 8,500-10,000 Mc. range; has direct-tuning and direct-reading dials; is essentially a signal generator providing a max. rf. output of 0.223 v.; may



be modulated with high-quality pulses of 0.05 usec. rise time; may be FM modulated. Separate receiver section measures external rf. power or external frequency, and special circuits assure that pulse power level is equal to CW level. Unit is fitted with coaxial terminals. Also announced is "Model 623" SHF test set with over-all frequency range of 5,925 to 7,725 Mc. and with operating frequency ranges determined by klystron tube installed. Six klystrons, with ranges of 300 Mc. each, are offered.—*Hewett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.*

Mention No. 658 when filling out card.

Sound-level Meter

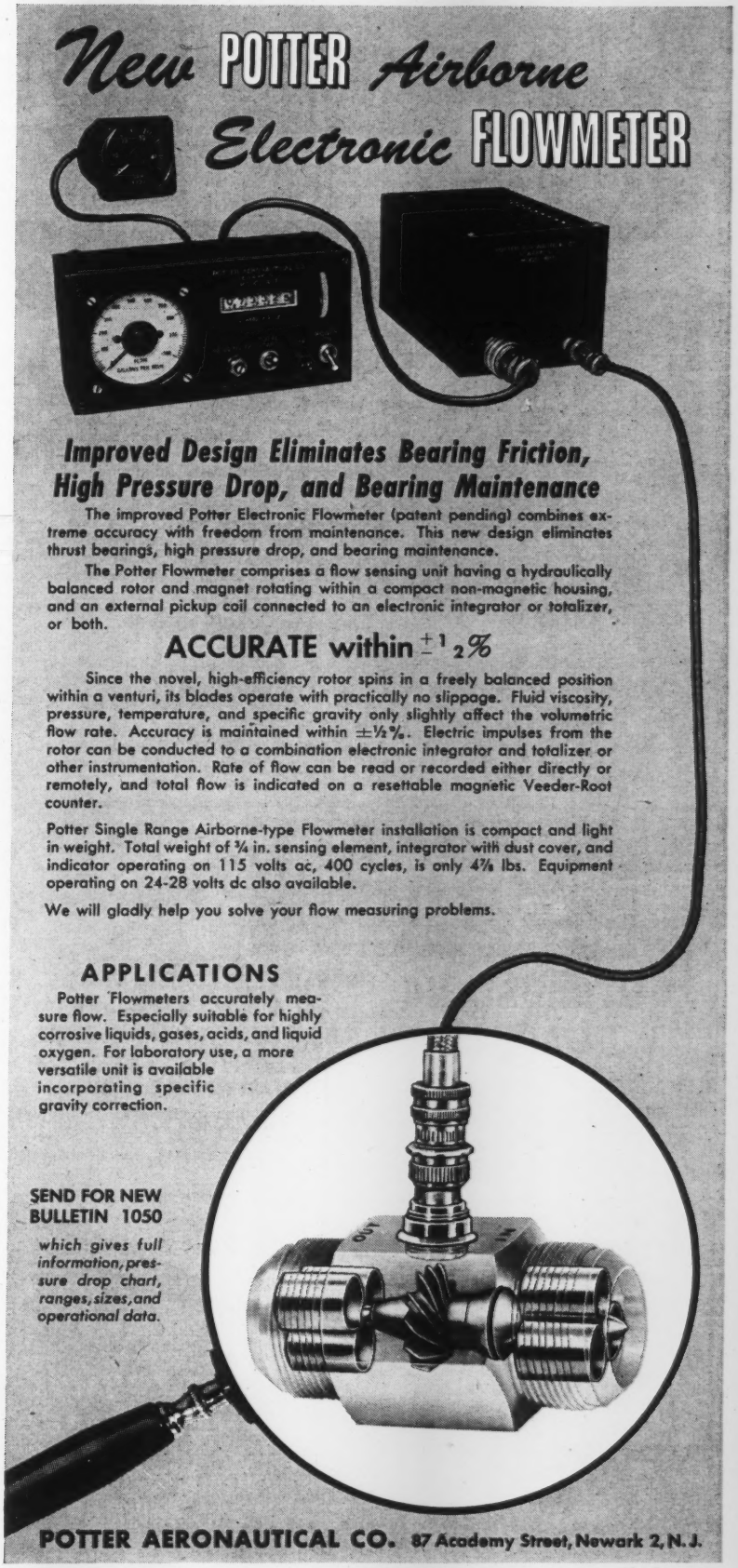
New "Type 1551-A Sound-Level Meter" measures product noise in design department and in production; is suitable also for studying noise levels in working areas, for psycho-acoustic studies, etc. It has been designed to take advantage of new tubes, compo-

nents, and miniaturization techniques. It weighs 11 lbs., less than one-half weight of older "Type 759-B." All characteristics conform to ASA Specifications, and direct measurement of sound pressure levels can be made over a range from 24 to 140 decibels (a power range of 400 billion to 1). Diaphragm-type Rochelle-salt crystal microphone can be placed at end of a cable, or be replaced by another microphone with special characteristics. Output from "1551-A" can operate frequency analyzers, level and tape recorders, and oscillographs.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 659 when filling out card.

Harmonic Generator

New "Model 133 Harmonic Generator," fed by a 10-kc. square wave at 5 volts minimum, supplies harmonic voltages of this input at every 10-kc.


New POTTER Airborne
Electronic FLOWMETER
Improved Design Eliminates Bearing Friction, High Pressure Drop, and Bearing Maintenance
The improved Potter Electronic Flowmeter (patent pending) combines extreme accuracy with freedom from maintenance. This new design eliminates thrust bearings, high pressure drop, and bearing maintenance.
The Potter Flowmeter comprises a flow sensing unit having a hydraulically balanced rotor and magnet rotating within a compact non-magnetic housing, and an external pickup coil connected to an electronic integrator or totalizer, or both.
ACCURATE within ±1/2%
Since the novel, high-efficiency rotor spins in a freely balanced position within a venturi, its blades operate with practically no slippage. Fluid viscosity, pressure, temperature, and specific gravity only slightly affect the volumetric flow rate. Accuracy is maintained within ±½%. Electric impulses from the rotor can be conducted to a combination electronic integrator and totalizer or other instrumentation. Rate of flow can be read or recorded either directly or remotely, and total flow is indicated on a resettable magnetic Veeder-Root counter.
Potter Single Range Airborne-type Flowmeter installation is compact and light in weight. Total weight of ¾ in. sensing element, integrator with dust cover, and indicator operating on 115 volts ac, 400 cycles, is only 4⅞ lbs. Equipment operating on 24-28 volts dc also available.
We will gladly help you solve your flow measuring problems.
APPLICATIONS
Potter Flowmeters accurately measure flow. Especially suitable for highly corrosive liquids, gases, acids, and liquid oxygen. For laboratory use, a more versatile unit is available incorporating specific gravity correction.
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which gives full information, pressure drop chart, ranges, sizes, and operational data.
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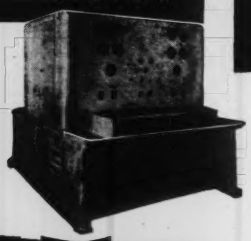
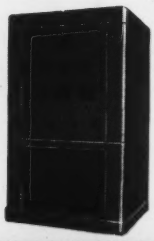
Cubicles

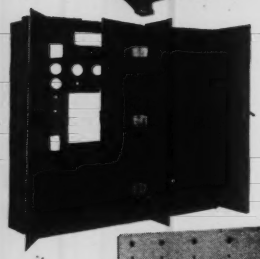


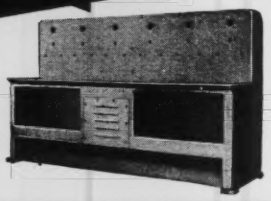
Cabinets



and

Control Boards





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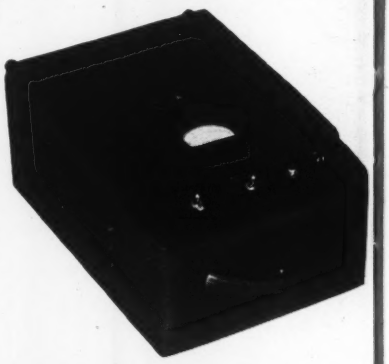
NEW INSTRUMENTS

point up to 15 Mc.; contains its own power supply, operates from standard 115-volt 50/60-cps. power, consuming 25 watts.—*Sierra Electronic Corp., 831 Brittan Ave., San Carlos, Calif.*

Mention No. 660 when filling out card.

Preamplifier

New "Model BL-954 High Gain AC Preamplifier" extends measurable range of recorders or CRO into microvolt region; maintains a relatively flat frequency response from 0.2 to 400 cps. It was designed for recording brain, heart and nerve potentials, as well as



research and industrial laboratory measurements. Voltage gain is 200,000 when operated push-pull. Instrument consists of three push-pull stages with balanced high-impedance input and capacitor-coupled output.—*Brush Development Co., Instrument Div.* 33, 3405 *Perkins Ave., Cleveland* 14, *Ohio.*

Mention No. 661 when filling out card.

CR Tube Reactivator

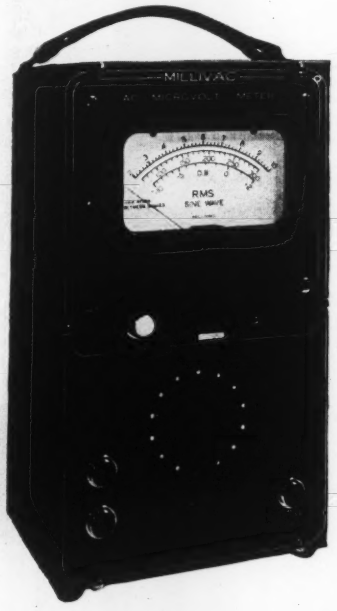
New "Cathode Tube Reactivator" is said to restore most low-emission TV tubes up to 80 percent of their original brilliance and add 50 percent to tube

life. Its action consists in speeding up rate of barium deposits by increasing cathode temperature and current to hasten formation of a new barium surface. Directions are simple to follow. Some tubes can be rejuvenated within 10 minutes.—*Rytel Electronics Mfg. Co.,* 11138 *Hawthorne Blvd., Inglewood* 2, *Calif.*

Mention No. 662 when filling out card.

Vacuum-tube Voltmeters

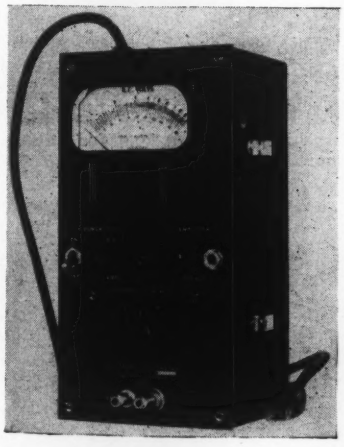
New "12-A" and "22-A" VTVMs have an unusual dial, designed to satisfy both linear and log scale requirements by a compromise, i.e., zero suppression of linear voltage scale to spread log db divisions for accurate reading. Both have exceptionally wide voltage range: 0.7 uv. to 1000 v. Frequency ranges: "12-A" 20 cps. to 250 kc., "22-A" 20 cps. to 6 Mc. without (and 10 Mc. with) correction chart. —*Millivac Instrument Corp.*, 444 *Second St., Schenectady 6, N. Y.*



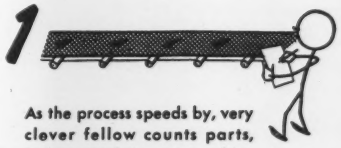
Mention No. 663 when filling out card.

Vacuum-tube Voltmeter

New "Type 170-A Electronic Voltmeter" for general laboratory and production use has amplifier section and power supply section as separate subassemblies to facilitate servicing. Amplifier is shock-mounted to minimize microphonics. It and power supply are electrostatically and magnetically shielded from each other and from ex-



YOU CAN DO THIS *automatically*



1 As the process speeds by, very clever fellow counts parts, inches, revolutions or machine operations up to 60,000 per minute without a mistake . . .

with a Potter Instrument Company, Inc.

2 At a precise preselected count short of the total, alert foreman signals for reduced speed or other preliminary control action . . .

Two Sequence Predetermined Electronic Counter

3 When final predetermined count is reached, gates close, shears cut or other machine control takes place—on the fly, without stopping . . .

4 With operation completed, tireless manager instantaneously calls for complete recycle without missing a count.

faster without human error

Potter instruments are working for manufacturers in every industry—controlling everything from the number of zips in a zipper to the number of pills in a bottle.

Potter counters can solve your problem if high speed and precise control are needed. No more flexible method of preselecting one, two or more counts in sequence exists. There are no moving parts, therefore wear, slippage and inertial effects are eliminated.

Have you a counting problem? We'd like to help.

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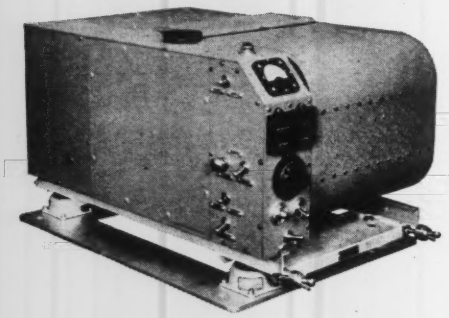
Century MODEL 408

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



After conducting a nation-wide survey among the users of oscillograph equipment and carefully considering the problems which have confronted them for a number of years, Century is proud to offer the Model 408 Oscillograph. This Oscillograph has been designed and built expressly for mobile and airborne operation. As with all Century products, this oscillograph incorporates the utmost in modern design and workmanship, yet it remains simple in its operation and maintenance.

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Eliminates Snubbers— It Can't Plug—

The Most Significant Pressure Gage Development in 50 Years.

For the first time, a successful means of eliminating the effect of pulsation and shock on pressure gage mechanisms has been developed which DOES NOT introduce an orifice or restriction in the pressure connection. ***It Can't Plug***

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ELECTRONICALLY REGULATED
LABORATORY POWER SUPPLIES

BENCH MODEL 50

- **INPUT:** 105-125 VAC, 50-60c
- **OUTPUT #1:** 0-500 VDC at 500 ma regulated
- **OUTPUT #2:** 0-50 VDC, 0-200 VDC Bias Output.
- **OUTPUT #3:** 6.3 VAC at 5A unregulated
- **OUTPUT #4:** 6.3 VAC at 5A unregulated
- **RIPPLE OUTPUT:** Less than 8 millivolts rms

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LAMBDA ELECTRONIC

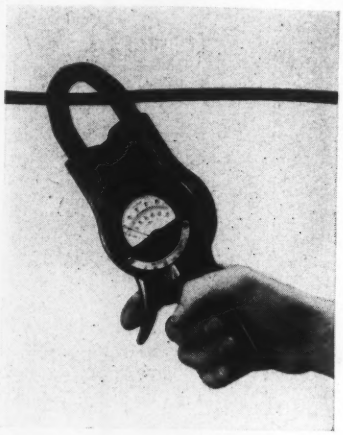
NEW INSTRUMENTS

ternal fields. This eliminates pickup, minimizes amplifier hum, prevents disturbing nearby equipment. No need of selected tubes for replacement: any standard tube may be substituted without affecting characteristics. Range 0.001 to 100 volts; accuracy 2 percent over 10-250,000-cps. frequency range.—*The Daven Company*, 191 *Central Ave., Newark* 4, *N. J.*

Mention No. 664 when filling out card.

Clamp-type Volt-ammeter

New "Type AC-1" volt-ammeter supplements maker's line of "Tong Test" ammeters. Readings are made without breaking circuit or insulation. Jaws will



accommodate cables up to 1.5 in. diameter and bus bars up to 2 x 0.5 in. Four current ranges available: 0-12, 0-60, 0-120, 0-600 a-c. amperes. Voltage leads are safely plugged into handle; two voltage ranges available, 0-150, and 0-600 a-c. volts. Accuracy 3 percent of full-scale deflection.—*Columbia Electric Mfg. Co.*, 4553 *Hamilton Ave., Cleveland* 14, *Ohio.*

Mention No. 665 when filling out card.

Wow-meter

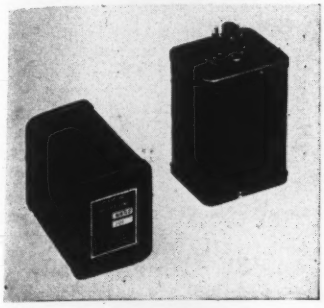
The "Type 152A Wow-Meter" indicates both frequency variations ("wow") and center frequency in center-frequency range 800 to 1250 cps.; built-in frequency meter calibrated 600 to 1500 cps. (other ranges to order). Frequency- and wow-measuring circuits employ a new principle based on characteristics of new magnetic materials and maker's static frequency-to-voltage translating unit that produces an output voltage directly proportional to input frequency and

independent of signal amplitude. Available full-scale wow sensitivities are 0.3, 1.0, and 3.0 percent. Three wow spectra: 0.5 to 10, 0.5 to 120, and 10 to 120. Instrument includes dual-regulated power supply.—*Minnesota Electronics Corp., St. Paul, Minn.*

Mention No. 666 when filling out card.

Plug-in High-gain Amplifier

New miniature plug-in amplifier is potted in a steel case to minimize microphonics. Maximum gain 9000; flat frequency response from 2 to 1000 cps.

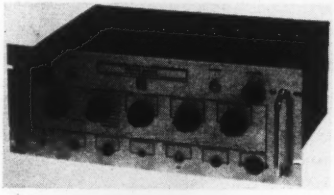


Power supply requirements 600-ma. 6.3-v. filament supply and 0.5 ma. 250-v. plate supply. Maximum output voltage 20 v. Amplifier will accept an extraordinary amount of negative feedback without instability.—*Dep't A, Engineering Research Associates, Inc.*, 1902 *West Minnehaha Ave., St. Paul* 4, *Minn.*

Mention No. 667 when filling out card.

Universal Amplifier

New "Model BL-360" universal amplifier (carrier type), for standard 19-in. rack, was designed for use with maker's Magnetic Direct Writing Os-



cillographs in studies of static or dynamic strains up to 100 cps. when measured by use of resistance-sensitive strain gages. Pressures, temperatures, torque, accelerations and forces may be recorded likewise.—*The Brush Development Co., Instrument Div.* 33*D*, 3405 *Perkins Ave., Cleveland* 14, *Ohio.*

Mention No. 668 when filling out card.

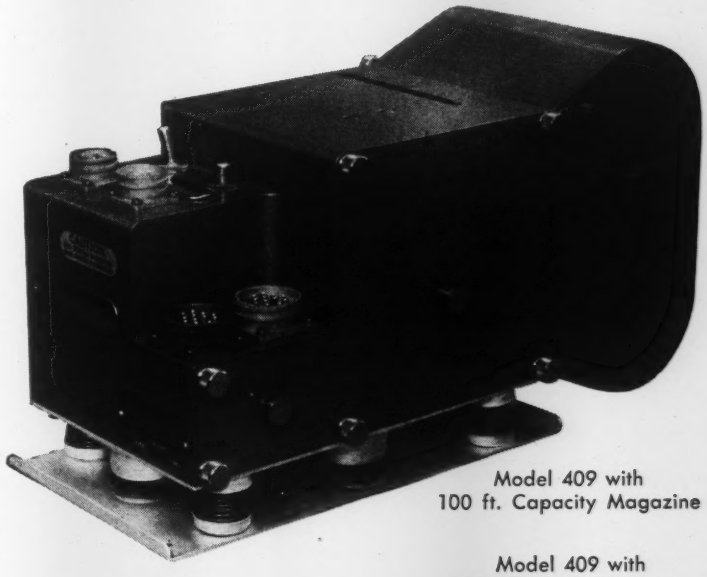
Power Rectifiers

New "Powersel" selenium rectifiers are rated at a higher wattage per unit of volume than is usual for their type. This rating is said to be made possible by "a unique manufacturing process which produces rectifier plates of extremely high reverse resistance and extremely low forward resistance." Aluminum base plates and aluminum hardware minimize weight. Units can be supplied in a variety of electrical configurations and ratings; can be

Century MODEL 409

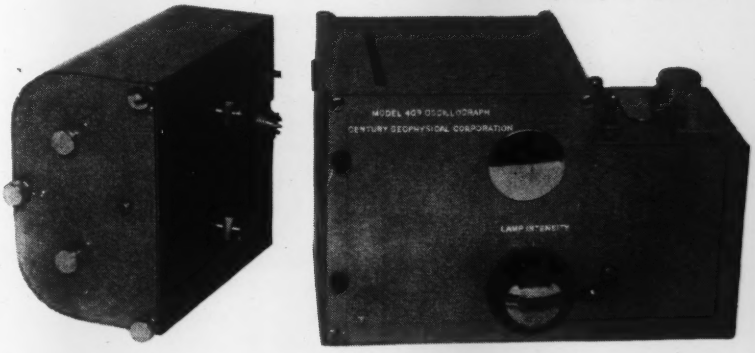
RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



Model 409 with
100 ft. Capacity Magazine

Model 409 with
50 ft. Capacity Magazine



The Century Model 409 Oscillograph was designed for operation under the most adverse conditions and more especially, where space and weight considerations are limited.

This Oscillograph is the smallest and most compact unit available on the present market, yet it incorporates many features found in larger oscillographs, such as trace identification, trace viewing, continuously variable paper speeds and others. The Model 409 Oscillograph has been tested and proven to record faithfully during accelerations in excess of 20 g's. This makes it especially desirable for uses such as missile launching, parachute seat ejection, fighter aircraft and torpedo studies.

Write for Bulletin CGC-303 and CGC-301

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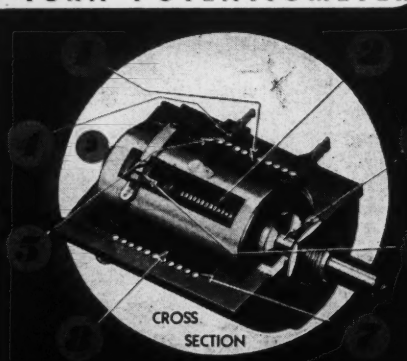
PRECISION TEN-TURN POTENTIOMETER

1. You get permanent accuracy because the resistance wire is locked in place. It is precision positioned and moulded integrally with the housing.
2. You get permanently accurate settings, smooth action and low uniform torque provided by the stainless steel, precision ground, double thread lead screw guiding the moving contact.
3. You get precise positioning of the moving contact because of the two bearings supporting the rotor assembly.
4. You get good rigid terminals because they are moulded integrally with the housing.
5. Terminals soldered to ends of resistance element before moulding. Entire resistance circuit is an integral part of the housing.
6. You get accurate setting and resetting due to anti-backlash spring in contact guide.
7. You get a fine resolution because of the 43½" length of resistance wire in the spiral element.
8. You get a resistance output directly proportional to shaft rotation within ±0.1% of the total resistance. Every potentiometer is automatically machine tested for linearity at 101 points.



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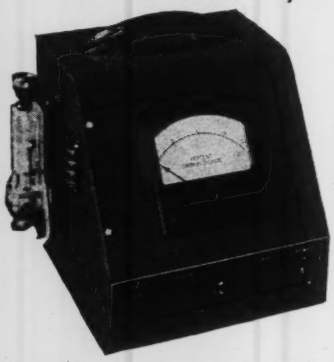

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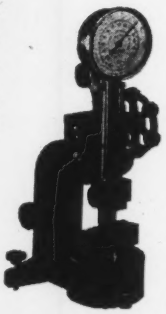

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Illustrated bulletins free

The Shore Instrument & Mfg. Co., Inc.

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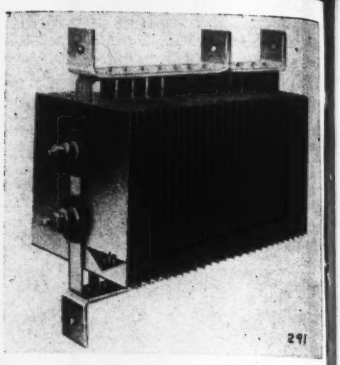
NEW INSTRUMENTS



coated with special protective finishes or hermetically sealed.—*Electronic Devices, Inc.*, 429 12*th St.*, *Brooklyn* 15, *N. Y.*

Mention No. 669 when filling out card.

TV Camera Dolly

New "Mobil-Mount" dolly facilitates TV camera manipulation and movement: one-hand steering lever turns all four wheels simultaneously; indicator graduated in degrees allows predetermined settings.—*Allen B. Du Mont Laboratories, Inc.*, 1500 *Main Ave.*, *Clifton, N. J.*

Mention No. 670 when filling out card.

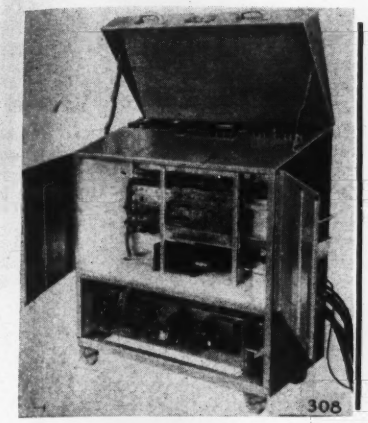
TV Components

New "Stancor" television replacement components include six power transformers; two filament transformers; two horizontal deflection and high voltage transformers; two filter chokes; a vertical deflection output transformer and a width control with AGC winding.—*Standard Transformer Corp.*, 3580 *Elston Ave.*, *Chicago, Ill.*

Mention No. 671 when filling out card.

Aircraft Circuit Tester

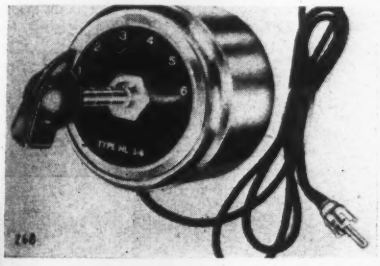
New "Bogue Nacelle Tester" can check 200 aircraft electric circuits in "less than ten seconds" by means of rapid-disconnect plugs. Power for servos, supercharger controls, etc., is provided by m-g. set. Tester was primarily designed for use in factory production of power nacelles; is equally suitable for pre-flight tests; includes facilities for checking variable-pitch propellers. —*Bogue Electric Mfg. Co., 52 Iowa Ave., Paterson 3, N. J.*



Mention No. 672 when filling out card.

Playback Equalizer

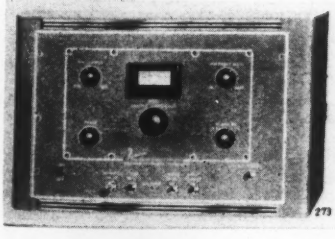
New "Type HL 1-6" playback equalizer is a passive network affording a choice of six switch positions for various recording curves used by domestic and European manufacturers in making standard and microgroove records. —*Radio Shack Corp., 167 Washington St., Boston 8, Mass.*



Mention No. 673 when filling out card.

Fundamental Oscillator

New "Type 907" fundamental oscillator is continuously tunable over frequency range of 35 to 900 Mc.; features a novel tank circuit design that permits a 30-to-1 tuning range with an output voltage of not less than 1 volt



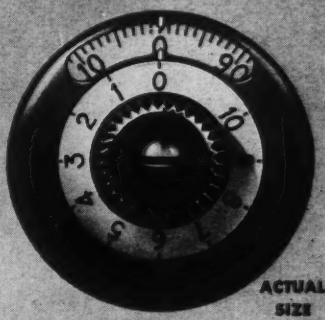
MICRODIAL
TEN TURN-COUNTING DIAL

Microdial is composed of two concentrically mounted dials . . . one for counting increments of each turn and the other for counting turns. The incremental dial has 100 equal divisions and is attached rigidly to the shaft so there is no backlash. Thus the contact position is indicated to an indexed accuracy of 1 part in 1000. Rotation is continuous in either direction. There are no stops on the Microdial assembly.

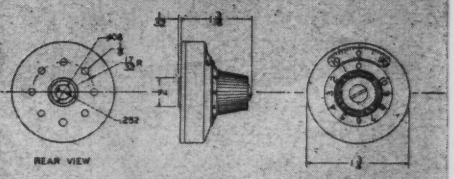
COMPACT . . . Microdial has same O.D. as Micropot . . . requires no more panel space.

CLEAR READING . . . Forced fast-reading tests showed only 1/20th as many errors with Microdial open window as with next most legible dial. Turn counter distinguishes between 0 and 10 turn readings, and accelerates to avoid confusion on readings near integral turns. Precise readings are made from larger dial with maximum separation of graduations and wide angle visibility.

CONVENIENT . . . delivered completely assembled with dials synchronized. Easily mounted in a few seconds. All dials may be locked.



ACTUAL SIZE



REAR VIEW

Microdial . . . turn-counting dial, primarily designed for use on Micropot ten turn linear potentiometers . . . use it on any multiturn device having ten turns or less.

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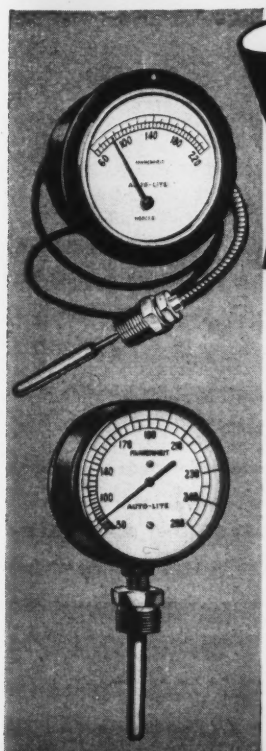

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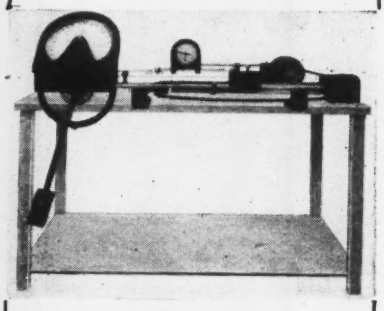

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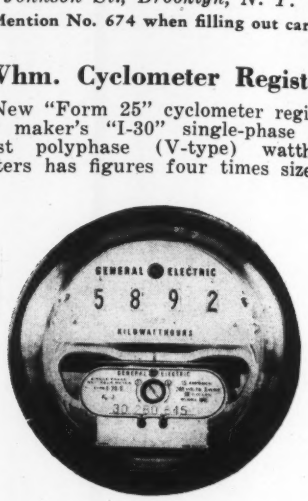
NEW INSTRUMENTS

across 75 ohms at all frequencies. A video type blanking circuit provides a true horizontal zero base line.—*Polytechnic Research and Development Co., 55 Johnson St., Brooklyn, N. Y.*

Mention No. 674 when filling out card.

Whm. Cyclometer Register

New "Form 25" cyclometer register for maker's "I-30" single-phase and most polyphase (V-type) watthour meters has figures four times size of

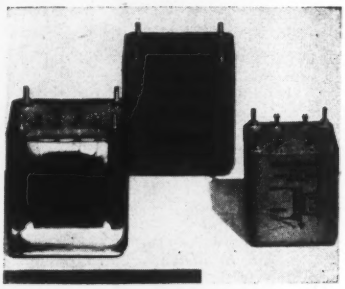


average cyclometer-register figures. A unique magnetic storage and release effect eliminates partly turned or obscured figures.—*General Electric Co., Schenectady, N. Y.*

Mention No. 675 when filling out card.

Transformers

New hermetically-sealed transformer with cast-permafil construction, for use in radar and other military electronic equipment, is said to be first

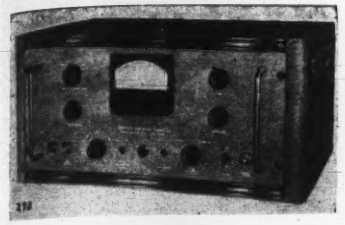


solventless-resin type transformer with sufficient moisture protection to meet a specification written for metal-enclosed hermetic units; satisfies all MIL-T-27 Grade I requirements; is smaller and lighter than present models; has fewer machined or punched parts.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 676 when filling out card.

Standing-wave Amplifier

New "Type 275 Amplifier" is a high-gain linear audio amplifier which indicates voltage standing-wave ratios over full-scale ranges of 1:1.3, 1:3, 3:10, 10:30, and 30:100. A normalizing gain control channel minimizes effect of power drift on r-f source. Unit

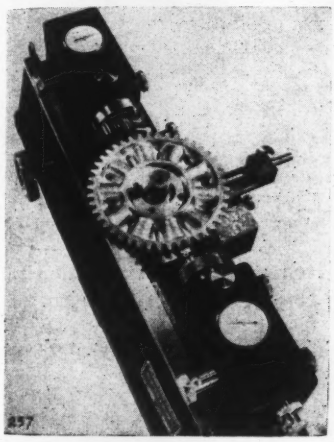


may be operated as either a broadband amplifier over the range of 300 to 3000 cps. or as a narrow-band amplifier at 500, 1000, and 1300 cps. with a 25-cps. pass band. Noise level is 0.03 mv.; full-scale narrow band sensitivity is 0.1 mv.—*Polytechnic Research and Development Co., 55 Johnson St., Brooklyn, N. Y.*

Mention No. 677 when filling out card.

Gear Helix-angle Checking Device

New adaptor for maker's Gear Checker simplifies set-up for checking

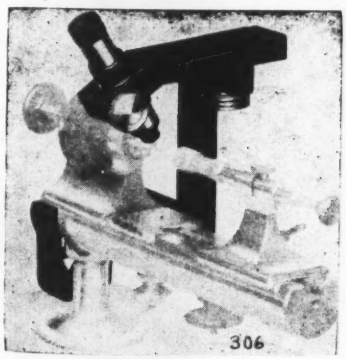


helix angle: practically eliminates mathematical computations. — *Orlandi Gear and Machine Co., 16195 Meyers Road, Detroit 27, Mich.*

Mention No. 678 when filling out card.

Jeweler's-lathe Microscope

New wide-field microscope can be attached to a jeweler's lathe for inspection of work in operation; provides fixed magnification of 20X or 40X; swings out of work's way without losing focusing adjustment; can be provided with or without a reticle,



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One-piece acrylic plastic body with integral metering tube.
Top and bottom cleanout connections.
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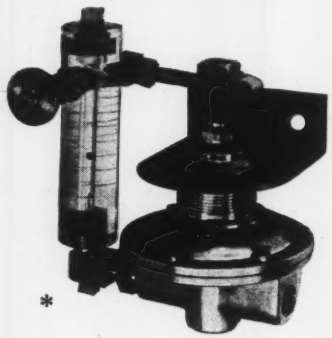
Safe working pressure 100 lbs.—Safe working temperature 180°.
Good chemical resistance; chlorine, photographic solutions, principal acids.
Flow rates: 0.2 CFH to 3 CFM of air; .01 GPH to 3 GPM of water.



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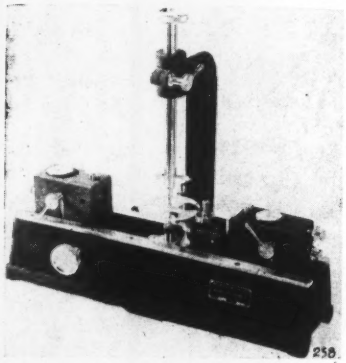
NEW INSTRUMENTS

which comes in either millimeters or thousandths of an inch for measuring depths of cut, contours and dimension of small parts, etc.—*Div. I, Pacific Transducer Corp.*, 11921 *West Pico Blvd., Los Angeles* 64, *Calif.*

Mention No. 679 when filling out card.

Gear-checking Attachment

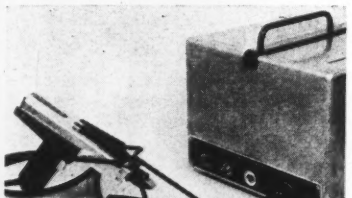
New "Rolling Attachment" for maker's Gear Checker makes possible rapid check of pitch diameter and concentricity to 0.0001 in.; also check of backlash with mating gears or master gears.—*Orlandi Gear and Machine Co.*, 16195 *Meyers Road, Detroit* 27, *Mich.*

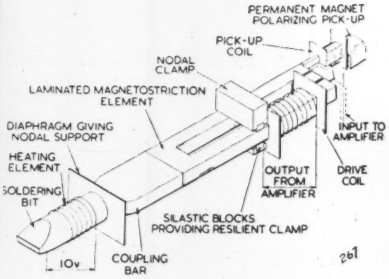


Mention No. 680 when filling out card.

Ultrasonic Equipment for Tinning and Soldering

New English-made "Type E7587" ultrasonic soldering equipment vibrates tip of iron at about 20 kc., thereby breaking up oxide film on aluminum and its alloys and hence making possible soldering and tinning.—*International Electronics Corp.*, 137 *Hudson St., New York* 13, *N. Y.*





Mention No. 681 when filling out card.

Timer for Scalers

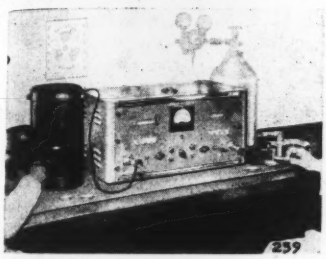
New "Model T100" timer registers elapsed time in hundredths of minutes; operates with maker's (and similar)

scaling instruments; can be quickly reset to zero.—*Nuclear Instrument & Chemical Corporation, 229 West Erie Street, Chicago 10, Illinois.*

Mention No. 682 when filling out card.

Twin Scaler

New twin scaler, said to be "two scalers for the price of one," comprises a Higinbotham binary scaler with two input connectors, two scales-of-16 and two registers, each operating independently. Single high-voltage power

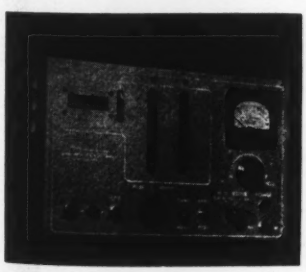


supply employs two separate regulating circuits: one for each G-M tube. Counting rates (in excess of 20,000 per minute) independently registered on each Veeder-Root register. When more rapid counting is desired from a single detector, a switch is thrown, making a single Higinbotham scale-of-256 totalizing on one register.—*Radiation Counter Laboratories, Inc., 5122 W. Grove St., Skokie, Illinois.*

Mention No. 683 when filling out card.

Laboratory Scaler

New "Model DS-606 Poli-Scaler," easily adaptable to GM and scintillation counting, features a plug-in power supply adjustable to any voltage from



0 to 2.5 kv, positive or negative, and two plug-in "Model TU-9" decade totalizing units which feed into a high-speed mechanical register. Pulses can be

The S.S. WHITE 80X HIGH VOLTAGE RESISTOR

(½ Actual Size)

4 watts • 100 to 100,000 megohms

Developed for use as potential dividers in high voltage electrostatic generators, S.S. White 80X Resistors have many characteristics—particularly negative temperature and voltage coefficients—which make them suitable for other high voltage applications.

They are constructed of a mixture of conducting material and binder made by a process which assures adequate mechanical strength and durability. This material is non-hygroscopic and, therefore, moisture - resistant. The resistors are also coated with General Electric Dri-film which further protects them against humidity and also stabilizes the resistors.

WRITE FOR BULLETIN 4906

It gives complete information on S.S.White resistors. A free copy and price list will be sent on request.

THE S.S.White INDUSTRIAL DIVISION
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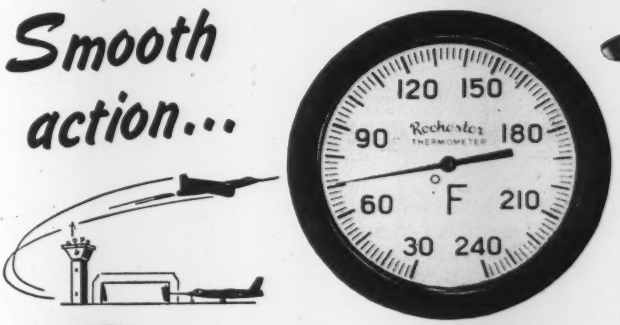

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react instantly to temperature changes!

• The superior dampening in ROCHESTER Dial Thermometers will never *"set-up"* or *"freeze"* the pointer in one position. It assures fast, smooth action at all times. New bimetallic elements never *"tire"* or lose their accuracy . . . take violent temperature change without error in indication.

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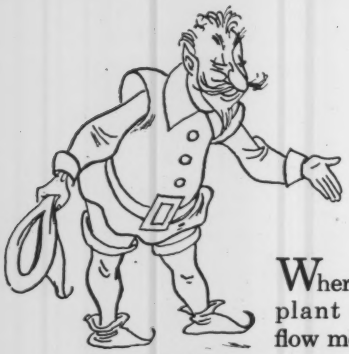


Wherever supervision of your plant processes requires flow measurement, Honeywell has the right instrumentation for the job.

Included are instruments specifically designed for accurate metering and flow cost-accounting of process fluids, with either linear or square root scales and continuous integration . . . with a choice of electric or pneumatic transmission from the metering point.

Flow-measuring systems, including proper control, are patterned to your exact requirements . . . offer you the advantages of Honeywell's single responsibility from sensing element to control valve. Each part of the system is designed and built with the needs of process designers, production engineers and instrument men foremost in mind.

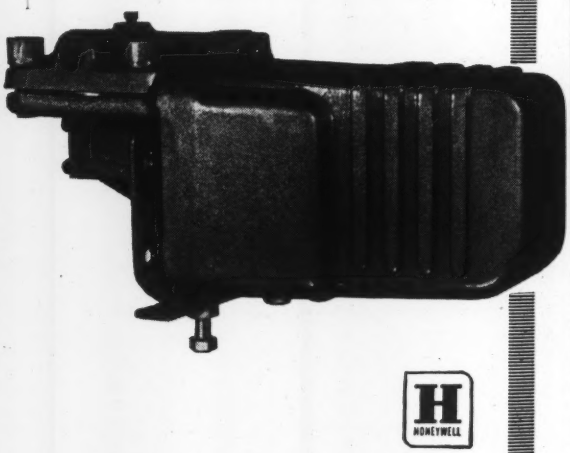
Call in our local engineering representative for a discussion of your application . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR Co., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Penna.

BROWN DIFFERENTIAL CONVERTER

This new flow transmitter, based on the pneumatic balance principle, is setting high standards of precision and simplicity in field operation. Using no mercury, seals or strainers, it converts the pressure differential at the metering orifice into a proportionate air output pressure which is a measure of flow. Response is rapid and accurate. Range is continuously adjustable from 20 to 200 inches of water, and is easily changed in the field without special tools or extra parts. Applicable to either liquids or gases, the Differential Converter is easily installed, cleaned and calibrated in the field.

For graphic panels and other applications requiring compact instrumentation, the Differential Converter is part of a new Honeywell flow control family which includes Tel-O-Set Indicators, Recorders and Controllers. Write for "*Centralized Instrumentation — Unlimited*," a new brochure describing types of Brown panelboards and instrument components available for industry.



● *Important Reference Data* . . . Write for Catalog No. 2281 on the Differential Converter...

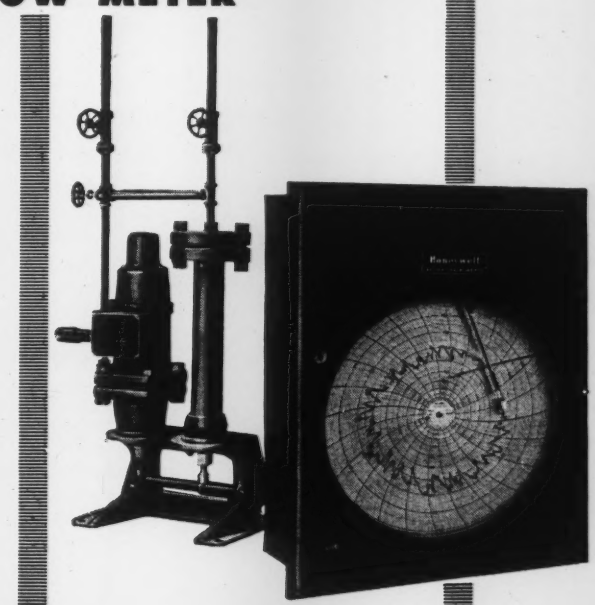
meter for every requirement

BROWN EVENLY GRADUATED FLOW METER

Features linear scale and electronic integration for simplified flow accounting...eliminates intermittent measurement and slow, complicated totalizing. Electronic integrator is simple, accurate, easily accessible for calibration and inspection. Precision-made meter body utilizes electric transmission for fast, sensitive remote recording. Also available with integral meter body (mechanical type). Characterized corrosion-resistant bell automatically provides straight-line flow measurement.

BROWN SQUARE ROOT FLOW METER

Costs for the distribution and utilization of fluids can be accurately determined with this instrument . . . available as a mechanical meter (with integral meter body) or as an electric meter (with electric transmission from remote meter body). Now equipped with electronic integration, it is available with a variety of meter bodies . . . including types for low pressure, intermediate pressure and all-purpose; as well as sealed armature and area types for special fluids. Interchangeable range tubes afford broad flexibility in the field.



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First in Controls

Catalog No. 293-1 on the Evenly Graduated Flow Meter... Catalog No. 2022 on the Square Root Flow Meter.

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• ENGINEERED
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for
PRECISION
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RUNNING TIME METER

• Designed for use on AC lines where successful servicing of electronic or electrical equipment depends upon the regular servicing of such equipment based on actual operating (or idle) time. Unit has a range of 9999.9 hours and resets automatically at 10,000 hours. Can be supplied for either 120 or 240 volts. 60 cycle operation and has operating temperature of —55 to +55° C.

• The Running Time Meter is housed in Burlington's attractive, black bakelite 3" square or 3½" round case.

• 9999.9 hour range
• 10,000 hour automatic reset
• —55 to +55° C. operating temperature. Write Dept. H-62 for further details.

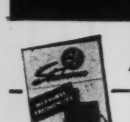
BURLINGTON INSTRUMENT COMPANY
BURLINGTON, IOWA

THE NEW 6T-4 Stroboconn

PRECISION STROBOSCOPIC FREQUENCY METER

MEASURES FREQUENCIES INSTANTLY BY PURELY VISUAL MEANS!

ACCURATE TO 0.05%



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Measures transient vibrations. Finds precise speed of rotating mechanical parts. Calibrates or checks precision tachometers, oscillators, other pulse generators. Used in place of bridge methods in measuring inductance and capacitance. Many other uses.

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NEW INSTRUMENTS

counted at a maximum rate of 1000 per second; direct readings to eight places. Additional scaling units (totalizers) can be used to increase counting rate capacity and total count capacity. Other features: pulse height discriminator and shaper (0 to 100 volts), voltage regulation and outlets for predetermined time or elapsed time clock, speaker, remote control and accessory count rate meter.—*Dep't 80, Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.*

Mention No. 684 when filling out card.

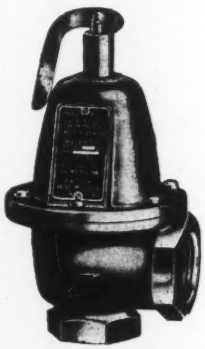
Beakers for Measuring Radioactive Solutions

New "Atomlab Blood Plasma Beaker" and "Improved Marinelli-type Beaker" are functionally standardized beakers for intercomparison of radioactive solutions. They are also used in performing rapid and effective routine radioactive investigations of solutions. Their immediate use is in field of radioisotope diagnosis, therapy, and research.—*Atomlab, Inc., 489 Fifth Ave., New York 17, N. Y.*

Mention No. 685 when filling out card.

Safety Relief Valve

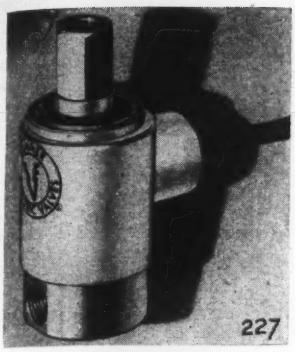
New "Type F-51" safety relief valve, tested and approved by the Natl Board of Pressure Vessel Inspectors, is for use on hot water space heating boilers, tanks, and heaters; available in pressure settings from 30 to 125 psi., with corresponding Btu. ratings at various pressure settings. It permits installing a valve which has a greater relieving capacity in Btu./hr. than particular boiler can generate.—*A. W. Cash Valve Mfg. Corp., Decatur 60, Ill.*



Mention No. 686 when filling out card.

Explosion-proof Solenoid Valve

New "Type X5" valve is essentially same general design as "Type V5" but with modifications to meet or exceed Underwriters Laboratories' requirements for Class I Group D explosion-proof construction. New: top nut has increased thread engagement and is flanged to increase leakage path; cap machined from solid steel and brazed to coil housing, and body which pro-

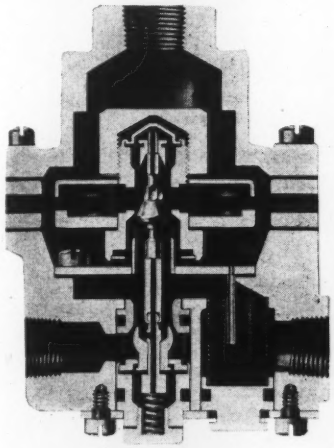


vides greater thread engagement with flange and is machined to lap-and-rabbet joint with coil housing. Most standard orifice sizes and pressure ratings are available. Valves can be supplied as two-way normally open or closed, and three-way normally open, closed, or directional flow.—*Skinner Electric Valve Div., Skinner Chuck Co., Norwalk, Conn.*

Mention No. 687 when filling out card.

Air Volume Booster

New "Model 20" air volume booster relay reduces transmission line lags, speeds up valve motors and air cylinders, permits maintaining (within 1



percent) ratio of loading signal to output pressure. It retains features of "Model 10" air pressure regulator: deep-convolution constant-area Nylon-inserted Neoprene diaphragms; statically and dynamically balanced valves; unit construction enabling user to inspect disconnecting air line. Available for pressure ratios of 1:1, 1:2, 1:3, 2:1 and 3:1.—*Kendall Controls Corp., 144 Moody St., Waltham 54, Mass.*

Mention No. 688 when filling out card.

UHF Power Triode

New "Type 6161" is a compact, forced-air-cooled power triode of grounded-grid type designed for UHF service in television and CW applications. Maximum plate dissipation 250 watts. Can be operated with full plate voltage and plate input at frequencies

Bendix-Friez

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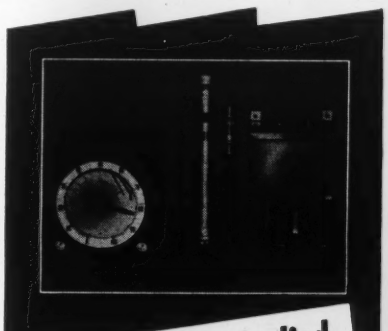


GAGETRON Applied to Measurement of Catalyst Level

New industrial application of atomic energy employs radium and hydrogen tube. Catalyst level is measured by number of atomic impulses passing through the counter tube. The primary element is the GAGETRON.

The GAGETRON is manufactured under Graham Patent No. 2,565,963.

FREE! Safety Code for use of radium. Also GAGETRON Bulletin No. 149.

INSTRUMENTS, INC.

122 N. Madison Tulsa 6, Okla.

Over 85% of the torque wrenches used in industry are

STURTEVANT TORQUE WRENCHES

Read by Sight, Sound or Feel.

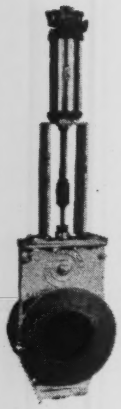
- Permanently Accurate
- Practically Indestructible
- Faster—Easier to use
- Automatic Release
- All Capacities

in inch ounces . . . inch pounds . . . foot pounds All Sizes from 0-6000 ft. lbs.

Every manufacturer, design and production man should have this valuable data. Sent upon request.

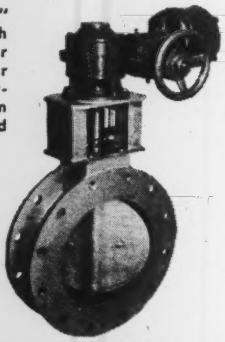
for Better Control and Shut-Off

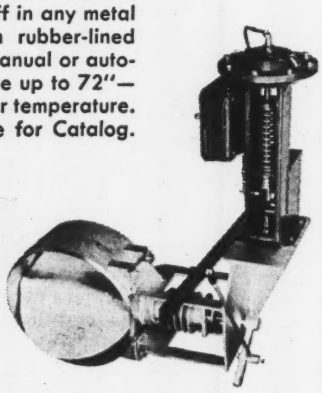
of Air • Gases • Liquids • Solids



Better choose Rockwell Butterfly or Slide Valves. You get commercially tight shut-off in any metal construction; drip or air-tight in rubber-lined metal valves. You can have any manual or automatic control mechanism. Pipe size up to 72"—and larger. High or low pressure or temperature. Easy to install and service. Write for Catalog.

"Kwikleen" slide valve with air cylinder operator; for handling carbon shapes in a hopper feed system.





Butterfly valve with electric motor and declutching mechanism for emergency handwheel operation; for handling water at 25 p.s.i.

Stainless steel butterfly valve for welding into pipe line; with air diaphragm operator and valve positioner; operation at 1600° F.

ROCKWELL VALVES

W. S. ROCKWELL CO. • 264 Eliot St., Fairfield, Conn.

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SOLVES INDUSTRY'S AUTOMATIC CONTROL PROBLEMS

THE ONLY 100% MERCURY SWITCH EQUIPPED CONTROLS

The distinguishing feature of Mercoid Controls is the exclusive use of Mercoid hermetically sealed mercury switches. These switches are not subject to dust, dirt or corrosion, thereby assuring better performance and longer control life.

Pressure | Thermostats Line Voltage | Temperature

Explosion Proof | Thermostats Low Voltage | Liquid Level

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Complete Mercoid Catalog sent upon request.

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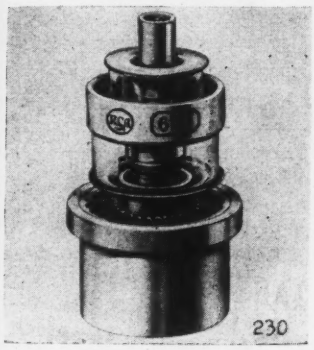
NEW INSTRUMENTS

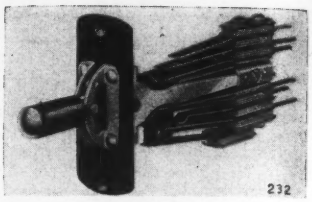


as high as 900 Mc. (up to 2000 Mc. with reduced ratings). Makers recommend it in place of "5588" for new equipment design.—*Tube Dep't, Radio Corporation of America, Harrison, N. J.*

Mention No. 689 when filling out card.

Lever Key Switch

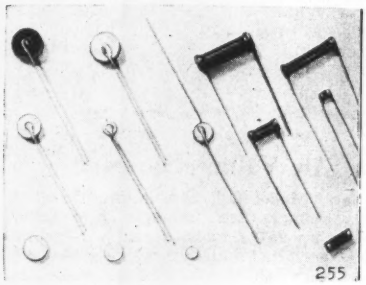
New "Shok-Lok" lever key switch, one in a series of telephone-type key switches, is especially designed to guard against tampering and to prevent accidental tripping caused by extreme vibration or shock. Mechanical locking device snaps into place when lever is operated into any one of three positions; is released by pressing a small button at end of lever handle. Key may be "double-locked" by turning handle, and cannot then be unlocked until handle is turned back.—*Automatic Electric Co., 1033 W. Van Buren St., Chicago 7, Ill.*



Mention No. 690 when filling out card.

Thermosensitive Resistors

New line of "NTC" semiconductive units comprises a variety of sizes and shapes. All have large negative temperature coefficients (1.2 to 5 percent per deg. C.) and stable and reproducible characteristics.—*Keystone Carbon Co., St. Marys, Penna.*



Mention No. 691 when filling out card.

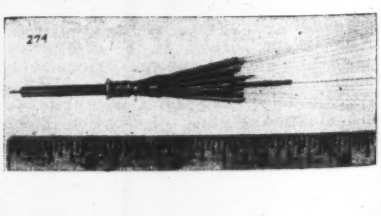
Wire-wound Resistors

New "Blue Jacket" vitreous-enamel wire-wound resistors meet Specification JAN-R-26A; are available in complete range of military styles RW29 to RW39. —*Sprague Electric Co., 43 Marshall St., North Adams, Mass.*

Mention No. 692 when filling out card.

Subminiature Slip-ring Assembly

New subminiature slip ring assembly incorporates 32 slip rings with individual color-coded leads; over-all length is 1.011 in.; ring width 0.020 in., barrier width 0.010 in., ring diameter

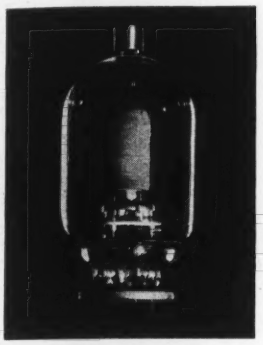


0.141 in. Assembly meets specified insulation requirements of 500 volt hi-pot intercircuit.—*Electro Tec Corp., South Hackensack, N. J.*

Mention No. 693 when filling out card.

Clipper Diode

New "Los Gatos Type 719A" 75-watt clipper diode is for use in pulse generators where pulse-repetition rate is 2000 pps. or less and peak forward

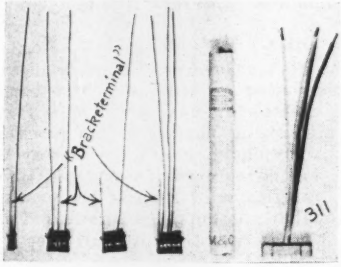


current is 10 amps. Peak inverse rating is 25000 volts. Tube incorporates a new black-body heat-dissipating anode surface termed "Sintercote." Heater draws 7 amps at 7 volts. Tube fits standard No. 234 socket.—*Lewis & Kaufman, Inc., Los Gatos 30, Calif.*

Mention No. 694 when filling out card.

Miniature Rectifiers

New "Series 280" rectifiers (left) feature "ERM" (external resilient member) construction and "bracke-terminal" lug which may be bent to desired angle for mounting and cathode



connecting in one operation. New "Series 160-ERM" translator (right) is an assembly comprising two full-wave bridge rectifiers connected in opposed parallel so that they cannot rectify. Unit shown is designed for use in a newly-developed instrument circuit.—*Conant Labs, 6500 "O" St., Lincoln 5, Neb.*

Mention No. 695 when filling out card.

Circuit-marking Labels

New "E-Z-Codes" are pressure-sensitive identification units, coded alphabetically or numerically to user's specifications, for identification of circuits, parts, terminals, fuses, and switches.—*Westline Products Div., Western Lithograph Co., 600 E. Second St., Los Angeles 54, Calif.*

Mention No. 696 when filling out card.

Want rugged mounting of receivers or controllers without drilling or welding panel?

- WAIT FOR THE NEWS ABOUT *Taylor's* NEW AND GREATER TRANSET® CONTROL SYSTEM!

TAYLOR INSTRUMENT COMPANIES, ROCHESTER, N.Y., AND TORONTO, CANADA

AIDED BY

EAGLE timing

The Rock Island Millwork Co. of R. I., Ill. are now converting huge piles of waste sawdust into large sheets of "RESINWOOD," used in place of other hardboards for unlimited items such as door panels, cores, and the finest furniture.

Cycl-Flex

Bulletin 120

Eagle "Cycl-Flex" timers automatically operate a huge three-story press, repeating many properly timed delays for increased production and the highest quality product.

Completely enclosed time indicator moves toward "0" during timing, showing the remaining time.

There is an Eagle timer to fit your individual, industrial process to increase quality and production. Send for general bulletin 340, today.

EAGLE SIGNAL *Industrial Timers*

EAGLE SIGNAL CORPORATION MOLINE, ILL.

Wish all adjustments on your graphic panel recorder were easier to get at?

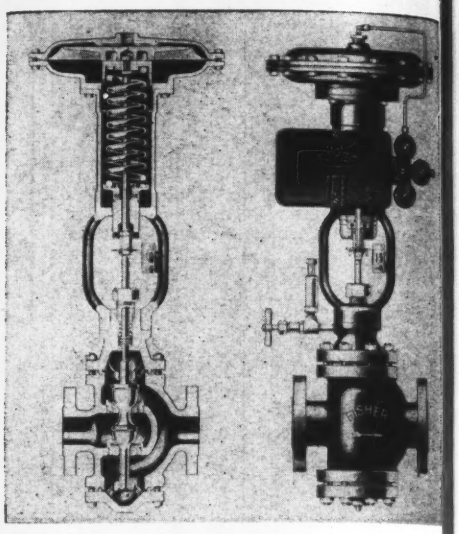
- WAIT FOR THE NEWS ABOUT *Taylor's* NEW AND GREATER TRANSET® CONTROL SYSTEM!

TAYLOR INSTRUMENT COMPANIES, ROCHESTER, N.Y., AND TORONTO, CANADA

Correlation of

Valve-sizing Methods

By G. F. BROCKETT, Fisher Governor Company



This comparison of three common methods of valve sizing is an important step leading to a standard acceptable to everyone. A society program for developing such a standard is needed.

DETERMINATION of the capacity of control valves and regulators has been a problem to every valve manufacturer and user since the industry began almost a century ago. Each manufacturer has attacked the problem independently in a manner often dictated by expediency, and there has been no correlation of results. The smaller companies have been handicapped by lack of test facilities and adequate engineering personnel, and there has been no organized attempt by any technical society to collect and coordinate information that is available.

Any method of valve sizing worthy of consideration must be based on experimental data because body coefficients cannot be predicted or determined mathematically. Thus it seems logical that the first step in unifying and standardizing the various methods of valve sizing in use today is to adopt a uniform method of capacity testing. Standard ratio of test-line size to valve size, standard locations for inlet and outlet pressure-taps, and standard methods of flow measurement would provide a basis for comparable test results throughout the industry. Each control-valve manufacturer undoubtedly has evolved individual company standards, and it should not be too difficult to combine these into one standard that would be acceptable to everyone. This is a subject that might be given consideration by the Standard Practices Committee of the Instrument Society of America.

This article discusses the relative merits of some current methods of valve sizing, and points out some pitfalls to be avoided. All test data presented was taken from production valves installed in either a four-inch or eight-inch flow-metering test-line in the Fisher Governor Company laboratory at Marshalltown, Iowa. The four-inch test line is shown in Fig. 1; the eight-inch line in Fig. 2. Air flows were metered with square-edged orifices equipped with flange pressure-taps. Orifice differential pressure was measured with differential manometers or strain-gage differential-pressure heads. Static pressure at the orifice, and inlet and outlet pressures at the test valve were measured with manometers, pressure gages, or strain-gage pressure heads. Valve travel was measured with a dial indicator or strain-gage cantilever-type motion indicator.

Water flows were measured with stop watch and weigh tanks, or over a V-notch weir. Pressure readings and valve travels for water flow tests were taken as described.

Valve body sizes from ½ inch through 2½ inches were tested in the four-inch metering line, and larger bodies were tested in the eight-inch metering line.

Any test setup differing appreciably from the setup described would give somewhat different results.

Presented at the Symposium, "The Use and Application of Control Valves," of the New Jersey Section, Instrument Society of America, Newark, N. J., April 1, 1952.

The C_v Method

For many years the Fisher Governor Company alignment charts or nomographs based on test data have been accepted widely in the control-valve industry. More recently the C_v method of valve sizing has come into prominence, largely because of its simplicity, and the relatively small amount of test work that is required. The symbol C_v represents the *liquid-flow coefficient* of a valve body assembly, and is numerically equal to the number of gallons of water per minute that a valve passes with a pressure drop of one pound per square inch. The C_v always must be determined by actual test. This method of valve sizing requires test work with low-pressure water only, although the C_v is used for determining all liquid, gas, or steam capacities. This makes the C_v method particularly attractive to the small company that does not have test facilities for air testing of large valves.

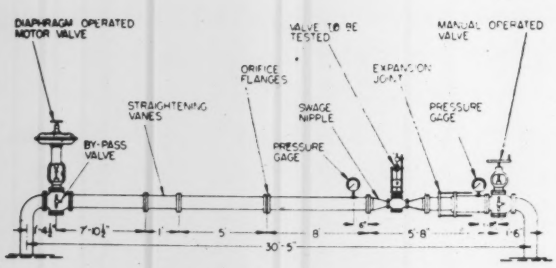


Fig. 1. Four-inch flow-metering test line.

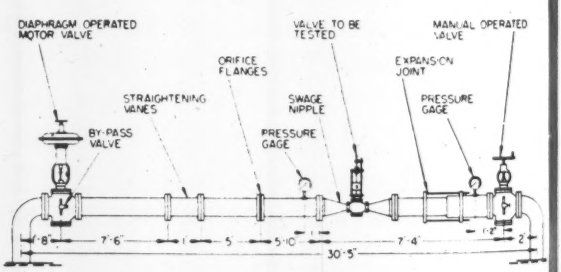


Fig. 2. Eight-inch flow-metering test line.

Liqid-capacity Chart

For globe-style bodies, either single or double ported, handling liquid flow, equation (1) gives accurate capacities and is generally used throughout the industry. Fisher liquid-flow alignment charts (Fig. 3) are based on this formula:

$$V = C_v \sqrt{\triangle P/G}, \qquad (1)$$

where V is the capacity of the valve in gallons per minute, C_v is the water capacity of the valve in gallons per minute with 1-psi. pressure drop, $\triangle P$ is the differential pressure across the valve in psi., and G is the specific gravity of the flowing liquid (based on water = 1).

If the fluid being handled by a valve has a viscosity (at flowing temperature) higher than 100 Saybolt Seconds Universal, a viscosity correction should be made. Little test data is available on the effect of viscosity on valve capacity, but the effect should not be overlooked. However, as the subject of capacity correction for viscosity is important enough to be the subject for an entire study, it is not discussed here.

Gas Capacity

Two different formulae for calculating gas capacity by the C_v method have been published and are in use today. These are:

$$Q = 1390\, C_v \sqrt{\triangle P(P_2)/GT} \qquad (2)$$

and

$$Q = 1364\, C_v \sqrt{\triangle P(P_1)/GT}, \qquad (3)$$

where Q is the quantity of gas flowing in cubic feet per hour at 60 deg. F. and 14.7 psia., C_v is the capacity of the valve in gallons water per minute with 1-psi. pressure drop (from test), $\triangle P^*$ is the differential pressure across the valve in psi., P_1 is the inlet pressure in psia., P_2 is the outlet pressure in psia., G is the specific gravity (air = 1), and T is the flowing temperature in degrees fahrenheit absolute.

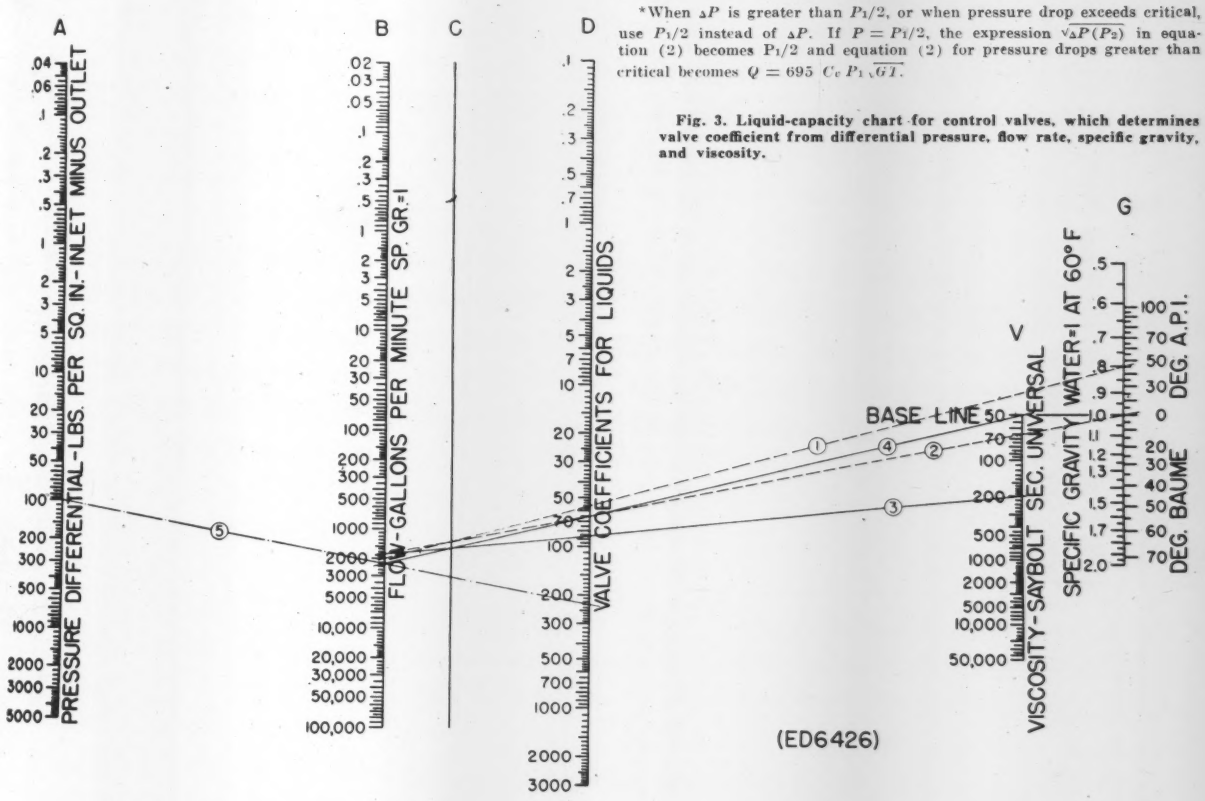
These two equations differ slightly in the numerical constant, but the difference in constant is so small as to be of little consequence. The important difference is in the fact that equation (2) uses outlet pressure P_2 whereas equation (3) uses inlet pressure P_1. Obviously both these equations cannot give correct capacities. This discrepancy between the two formulae increases with increase in $\triangle P$ and reaches a maximum of about 40 percent when $\triangle P/P_1$ is 0.5, or when pressure drop is critical.

GAS-CAPACITY CHART

A Fisher Governor Company gas-capacity alignment chart is shown in Fig. 4. Scales B, D, and F in this chart

*When $\triangle P$ is greater than $P_1/2$, or when pressure drop exceeds critical, use $P_1/2$ instead of $\triangle P$. If $P = P_1/2$, the expression $\sqrt{\triangle P(P_2)}$ in equation (2) becomes $P_1/2$ and equation (2) for pressure drops greater than critical becomes $Q = 695\ C_v P_1 \sqrt{GT}$.

Fig. 3. Liquid-capacity chart for control valves, which determines valve coefficient from differential pressure, flow rate, specific gravity, and viscosity.



Instructions for Using Above Chart for Liquid Flow

To determine coefficient of valve when differential pressure, flow rate, specific gravity, and viscosity are known:

1. Correct given rate of flow to the water equivalent if the specific gravity is different than 1.0 or the viscosity in Saybolt Seconds Universal is greater than 50 by the folllowing method:
   a) Draw a line between the points of flow on scale B and specific gravity of the liquid on scale G, and note point of intersection on line C. Draw a line between this point of intersection and the Base Line (specific gravity = 1) on scale G and extend this line until it intersects scale B. This point of intersection denotes flow corrected for specific gravity
   b) Draw a line between the point of corrected flow on scale B determined above, and viscosity of the liquid on scale V, and note point of intersection on line C. Draw a line between this point of intersection and the Base Line (viscosity = 50) on scale V, and extend this line until it intersects scale B. This point of intersection denotes flow corrected for viscosity
2. Determine the required valve coefficient by the following method:
   a) Draw a line between the point of differential pressure on scale A and the corrected flow point determined above on scale B, and extend this line until it intersects scale D. At this point on scale D, read the valve coefficient that will give the specified flow rate.

solve the equation $Q = CP_1$, (4)

where C is a constant determined by actual air test. This formula is used for pressure drops greater than critical, or where $\triangle P/P_1$ is greater than 0.5. Additional corrections are made for temperature and specific gravity. These corrections are mathematical and need not be discussed here. Note that the values determined on scale F are gas coefficients and not C_v. Inasmuch as coefficients are shown on scale F, it is necessary to have a table showing corresponding valve sizes and types. Valve size could be shown directly on scale F.

For pressure drops less than critical the charts solve the equation:

$$Q = CP_{1a},$$

where P_{1a} is an adjusted inlet pressure ascertained by solving an empirical formula. This empirical formula was derived from the results of extensive air tests with pressure drops less than critical on many types and sizes of control valves.

For each valve assembly tested an average coefficient

$$C = Q/P_1$$

was determined by running tests at more than critical pressure drop. Each valve then was tested with several different $\triangle P/P_1$ ratios between 0.0025 and 0.50. For each $\triangle P/P_1$ ratio, for each inlet pressure, and for each style of valve, a flow value Q_1 was established. The ratio of this flow to the flow at critical pressure drop will be called F. It was found that the F factors varied only with $\triangle P/P_1$

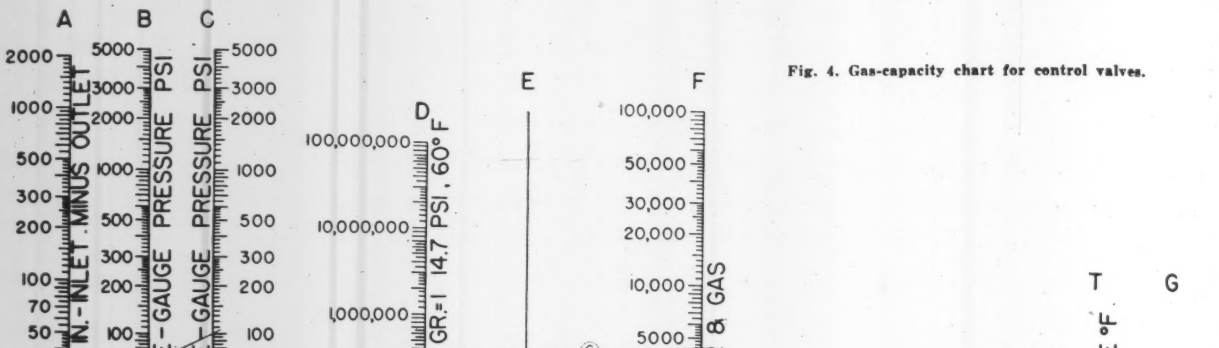


Fig. 4. Gas-capacity chart for control valves.

Instructions for Using Above Chart for Gas Flow

To determine coefficient of valve when inlet pressure, differential pressure, flow rate, specific gravity, and flowing temperature are known:

1. Correct given rate of flow to the air equivalent if the specific gravity is different than 1.0 or the flowing temperature is different than 60°F by the following method:
   a) Draw a line between the points of flow on scale D and specific gravity of the gas on scale G, and note point of intersection on line E. Draw a line between this point of intersection and the base line (specific gravity = 1) on scale G, and extend this line until it intersects scale D. This point of intersection denotes flow corrected for specific gravity.
   b) Draw a line between the points of corrected flow on scale D, determined above, and flowing temperature of the gas on scale T, and note point of intersection on line E. Draw a line between this point of intersection and the base line (temperature = 60°F) on scale T, and extend this line until it intersects scale D. This point of intersection denotes flow corrected for temperature.
2. Determine the required valve coefficient by the following method:
   a) Draw a line between the points of differential pressure on scale A and inlet pressure on scale C, and note the point of intersection with scale B.
   b) If the point of intersection on scale B is of lower value than the inlet pressure, extend a line from this point on scale B through the corrected flow point determined above on scale D, to scale F. At this point on scale F, read the valve coefficient that will give the specified flow rate.
   c) If the point of intersection on scale B is of greater value than the inlet pressure, disregard a) above and position the inlet pressure directly on scale B. Extend a line from this point through the corrected flow point on scale D to scale F. At this point on scale F, read the valve coefficient that will give the specified flow rate.

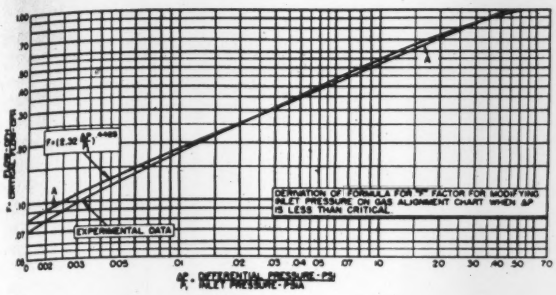

DERIVATION OF FORMULA FOR "F" FACTOR FOR MODIFYING INLET PRESSURE OR GAS ALIGNMENT CHART WHEN ΔP IS LESS THAN CRITICAL
EXPERIMENTAL DATA
A
ΔP - DIFFERENTIAL PRESSURE - PSI
P1 - INLET PRESSURE - PSIA

Fig. 5. Curve showing multiplying factors (F) for flow with less than critical pressure drop.

ratio. That is, for any given $\triangle P/P_1$ ratio, F was constant within the limits of experimental error, regardless of inlet pressure and style of value. Values of F are plotted against $\triangle P/P_1$ ratio on logarithmic coordinates in Fig. 5.

Note that this curve is nearly a straight line. A straight line A-A was drawn through this curve with a maximum error of less than 5 percent between $\triangle P/P_1$ values of 0.01 and 0.45 because $\triangle P/P_1$ ratios less than 0.01 seldom are encountered in sizing control valves, and capacities do not change appreciably with $\triangle P/P_1$ ratios higher than 0.45. Consequently it may be concluded that a valve-sizing method based on the straight line A-A is accurate enough for commercial practice.

The equation of this straight line is:

$$F = (2.32\triangle P/P_1)^{0.4425}$$

From the previous discussion:

$$P_{1a} = FP_1$$
$$= (2.32\triangle P/P_1)^{0.4425} P_1$$
$$= (2.32\triangle P)^{0.4425} (P_1)^{0.5575} \qquad (6)$$

The A, B, and C axes of the alignment chart in Fig. 4 solve equation (6). P_{1a} is represented by axis B, $\triangle P$ by axis A, and P_1 by axis C. B and C scales have been shifted to read psig. for convenience.

Comparison of Various Methods

We have now discussed three current methods for sizing control valves for gas flow—(1) using the C_v method and inlet pressure, (2) using C_v and outlet pressure, and (3) using the Fisher alignment chart. Figs. 6 and 7 compare results obtained by using each of the three methods. In both figures, $\triangle P/P_1$ ratios from 0 to 0.5 are plotted against flow of air at standard conditions in thousand cubic feet per hour. Fig. 6 is from test data on a Fisher 2-inch 300-psi. flanged globe body fitted with a 2-inch double-ported balanced throttle-plug inner valve. Fig. 7 is from test data on a Fisher 4-inch 250-psi. flanged-globe single-seated body fitted with a 4-in. straight-sided V-port inner valve. Air tests were run in both cases with 100-psia. inlet pressure.

In both Figs. 6 and 7, curve A was plotted from actual air-test data, and represents the true capacity of the valve. Curve B was plotted from data calculated by using formula (2) with a C_v determined by actual water test. Curve C was plotted from data obtained by using formula (3) and the same C_v value as used in curve B. Curve D is plotted from data obtained by using the Fisher alignment chart shown in Fig. 4.

Similar curves were plotted with other combinations of inlet pressure, valve size, and inner-valve type, with similar results.

These curves indicate that at $\triangle P/P_1$ ratio of 0.5, formula (2) gives capacities approximately 14 percent too low, and formula (3) gives capacities approximately 20 percent too high. Formula (3) gives about 40 percent higher capacities than formula (2). The Fisher alignment chart gives capacities at $\triangle P/P_1$ ratios of 0.2 about 5 percent low, and at $\triangle P/P_1$ ratio of 0.4 about 2.25 percent high. However, they give the exact capacity at $\triangle P/P_1$ of 0.5 (critical pressure drop) because they are based on test data taken at that point.

The trend of curves B and C indicates that either an equation of the form

$$Q = K\sqrt{\triangle P(P_2)/GT}, \text{ or}$$
$$Q = K\sqrt{\triangle P(P_1)/GT}$$

might give accurate results if the numerical constant were based on actual air test. However, without the corrections for specific gravity and temperature, a nomographic solution of either of these equations requires four axes instead of the three that are used on the basic Fisher chart.

The three methods of sizing valves for gas flow that have been discussed are probably not the only methods in use today. The three examples have been used merely to show some of the discrepancies that exist and to point out the need for standardization.

Steam Capacities

Steam capacities of control valves usually are determined by specific modifications of the methods used for gas. This is logical because steam is a gas whose behavior in general follows the gas laws. It can be shown mathematically, and has been proven by test, that gas capacities in cubic feet per hour can be converted with a high degree of accuracy to steam capacities in pounds per hour by a simple multiplying factor. This multiplying factor is close to 0.046, and is used in most formulae, charts, and slide rules for determining steam capacity. This means that steam capacities are determined with the same accuracy as are gas capacities because the same basic formulae are used.

Sizing Angle Valves

The preceding discussion has been directed toward the sizing of single- and double-ported globe-style bodies with turbulent flow and high Reynold's numbers. In construction of this type the valve body chambers are filled completely and there is little or no cavitation. When handling high-temperature hydrocarbons that tend to coke, or fluids with entrained solids that might cause excessive erosion, it often

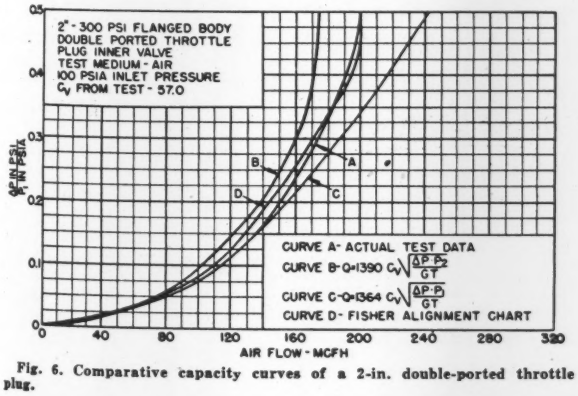

2"-300 PSI FLANGED BODY
DOUBLE PORTED THROTTLE
PLUG INNER VALVE
TEST MEDIUM - AIR
100 PSIA INLET PRESSURE
Cv FROM TEST - 57.0
ΔP IN PSI / P1 IN PSIA
AIR FLOW - MCFH
CURVE A - ACTUAL TEST DATA
CURVE B - Q = 1390 Cv √(ΔP P2 / GT)
CURVE C - Q = 1364 Cv √(ΔP P1 / GT)
CURVE D - FISHER ALIGNMENT CHART

Fig. 6. Comparative capacity curves of a 2-in. double-ported throttle plug.

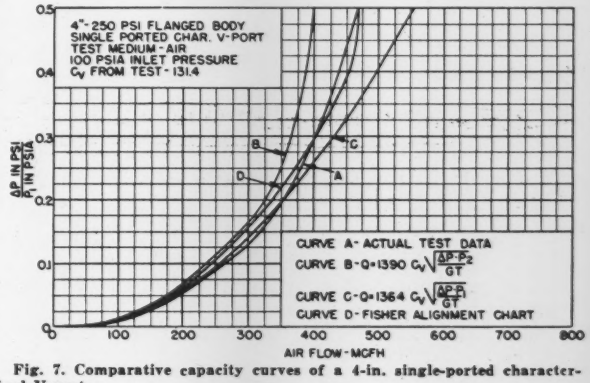

4"-250 PSI FLANGED BODY
SINGLE PORTED CHAR. V-PORT
TEST MEDIUM - AIR
100 PSIA INLET PRESSURE
Cv FROM TEST - 131.4
ΔP IN PSI / P1 IN PSIA
AIR FLOW - MCFH
CURVE A - ACTUAL TEST DATA
CURVE B - Q = 1390 Cv √(ΔP P2 / GT)
CURVE C - Q = 1364 Cv √(ΔP P1 / GT)
CURVE D - FISHER ALIGNMENT CHART

Fig. 7. Comparative capacity curves of a 4-in. single-ported characterized V-port.

is considered desirable to specify angle bodies with streamlined single-seated plug-type inner valves and venturi-shaped outlet nozzles. This type of construction is illustrated in Fig. 8. When valves of this type are installed with flow tending to close the inner valve, conventional methods of sizing often lead to serious error. This is particularly true if C_v values have been determined from tests run at low pressure drops.

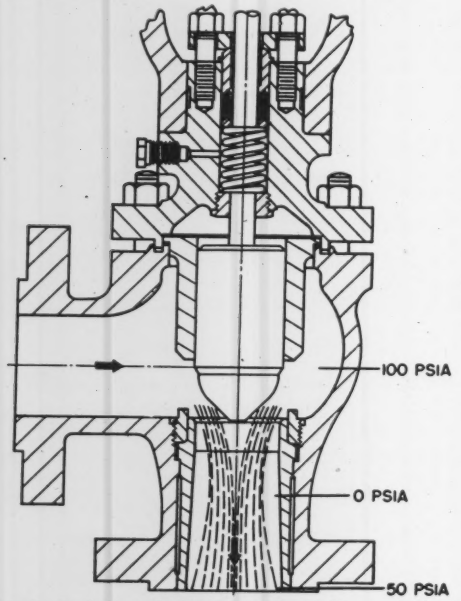


Fig. 8. Angle-type single-seated valve body, commonly used for high-temperature hydrocarbons, or for fluids with entrained solids.

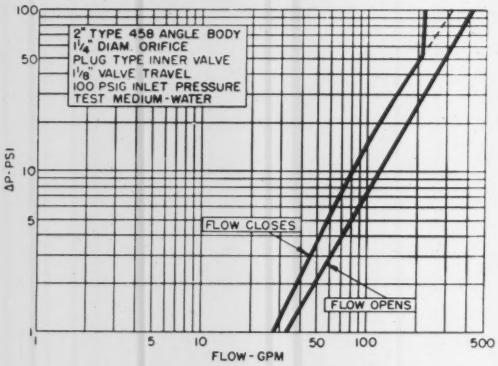


Fig. 9. Liquid-capacity curves of angle-body valve.

Liquid Flow

Fig. 8 shows the flow pattern and pressure conditions that might exist in a valve of this type with liquid flowing through the body. Laboratory tests indicate that when the pressure drop across the body exceeds approximately one-half the inlet pressure, the flow stream at the vena contracta does not fill the nozzle, leaving an annular ring where the pressure is equal to the vapor pressure of the liquid. This condition produces the maximum possible pressure drop across the inner-valve orifice, and consequently the maximum flow, with the given inlet pressure. Any further decrease in pressure in the outlet piping produces no appreciable increase in flow. The curve on the left in Fig. 9 illustrates the change in flow through a valve of this type with constant inlet-pressure and decreasing outlet-pressure. This curve was plotted from data on a 2-in. Fisher Type 458 body with an orifice of 1¼-in. diameter. The pressure at the inlet was held constant at 100 psig., and the outlet pressure in the downstream piping was varied from 0 to 100 psig. Water was the test medium. Note the point of apparent critical pressure drop when $\triangle P = 0.45P_1$ absolute. This point varied between 0.35 and $0.52P_1$ absolute with different valves and inlet pressures, but the average was about $0.45P_1$.

If body coefficient C_v were determined by test with $\triangle P$ less than $0.45P_1$, any capacity determinations where $\triangle P$ is greater than $0.45P_1$ would be in error. In fact, calculated capacities would follow the dotted line on the "flow closes" curve of Fig. 9, and a maximum capacity of 320 gpm. would be indicated, whereas the actual maximum is 220 gpm.

If the flow is reversed through an angle body of this type, normal methods of determining capacity can be used with accurate results. The capacity curve for the same 2-in. valve reversed in the line is shown on the right in Fig. 9, labeled "flow opens." With flow in this direction the capacity is higher also, owing to the increased efficiency as a result of better angle of approach to the nozzle.

Fig. 10 shows characteristic curves plotted from test data on a 2-in. angle body similar to that shown in Fig. 8. Note that when the valve is installed with flow tending to close the inner valve, the curve begins to break sharply at 50-percent stroke and maximum capacity is reached at about 75-percent travel. This is probably caused by the fact that the area of the flow stream at the vena contracta in the outlet nozzle is maximum at about 75 percent of the travel and, consequently, further valve opening does not increase the flow. However, if the flow is reversed through the body the maximum capacity is increased about 82 percent and the characteristic is much improved, as shown on the curve labeled "flow opens" in Fig. 10.

Gas Flow

With gas flowing through angle bodies of this type, the flow patterns exhibit the same tendencies as with liquids, although to a lesser degree. The curves in Fig. 11 were

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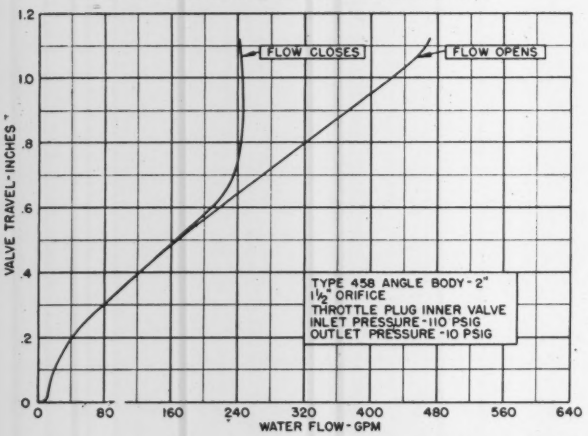

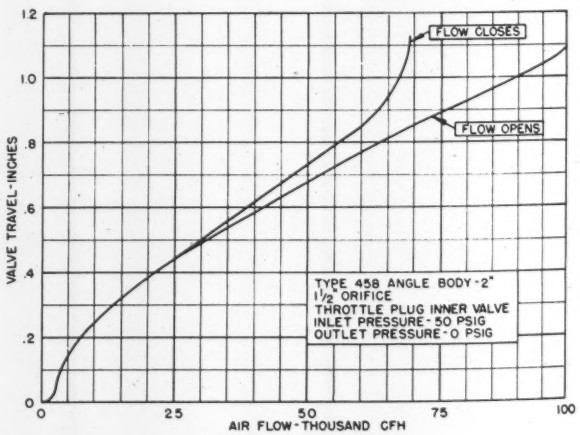

Fig. 10 (left). Characteristic curve of angle-body valve for liquid flow; Fig. 11 (right) for gas flow.

A-c. Measurements to 10,000 Cps.

By FRANK D. WEAVER

Electrical Instruments Section, National Bureau of Standards

ALTHOUGH alternating-current circuits operating at 60 cycles per second are the most common sources of power for electrical equipment in the United States, there are an increasing number of applications that require electrical current at frequencies of 400, 800, 1000, 2000, 5000, or 10,000 cycles per second. The conventional type of moving iron or electrodynamic instruments function well for measurements at normal power frequencies, but are not well adapted for measurements of electrical quantities at high audio frequencies. (See reference 3.) This article outlines methods and offers suggestions that will aid those who wish to obtain accurate measurements (better than 0.5 percent) of current and voltage at frequencies outside the usual frequency range (25-130 cycles) of the conventional ammeter and voltmeter.

Moving iron or electrodynamic type instruments that are compensated for use at frequencies up to 2500 cycles per second are commercially available. (See reference 2.) When in good condition these instruments may be relied upon to give values conforming to the manufacturers stated accuracy for any frequency up to this maximum. If greater accuracy is required when used within the manufacturers stated frequency limits, the instrument should be tested (corrections determined) for the particular conditions of use. These two types are not suitable for measurements of current and voltage over the full range of frequencies (25-10,000 cps.) discussed in this article.

The following four types of instruments are appropriate for measurements over the audio-frequency range: (1) rectifier, (2) electrostatic, (3) electronic, and (4) thermocouple. The first three are unsuitable for highly accurate measurement of current and voltage. The latter type, if correctly used, can serve as an accurate measuring device for measurements throughout the frequency range under consideration. With a few refinements (see reference 1) values accurate to a few hundredths of a percent can be obtained.

In the thermocouple instrument a heater element carries the current (alternating or direct) to be measured. The I^2R heating with rated current is sufficient to give a heater temperature of approximately 200 deg. C. A thermocouple junction connected to this heater is connected to a permanent-magnet moving-coil millivoltmeter. The current through the heater raises the temperature of the hot junction; the cold junction is at ambient temperature. This difference in temperature between the two thermojunctions provides sufficient emf. to deflect the moving system of a sensitive instrument. As the pointer indication is a function of the current through the heater wire the millivoltmeter scale can be calibrated as an a-c. or d-c. ammeter.

Error Sources

There are various sources of error in a thermocouple instrument. As a delicate and sensitive d-c. indicating instrument is used, it is subject to the errors of this type movement. In addition, measurements made with a thermocouple instrument are subject to errors from the following five sources: (1) skin effect, (2) capacitance effect, (3) inductance effects, (4) d-c. reversal differences, and (5) incomplete temperature compensation.

Skin effect can cause large errors at the higher frequencies. When used within the manufacturers specified frequency range the error from this effect is usually small. It is customary to use a fine wire or a thin tube of resistance material in designing the heater element to minimize this error.

Capacitance errors result from a shunting effect due to stray capacitance currents which tend to flow between any two electrical conductors at different voltages in the same a-c. circuit, thus "by-passing" the heater element. In other words, all the current in the circuit which one is trying to measure may not go through the measuring element. The manufacturer designs the circuit inside his instruments to minimize this effect. The user must give special consideration to the arrangement of components in his external test circuits to avoid errors, especially when measuring current and voltage in the upper audio or higher frequencies. (See reference 5.)

A-c. and d-c. differences in the thermal element itself are usually due to skin and capacitance effects. However, if the instrument is a voltmeter in which external resistance is added in series with the heater, or if it is an ammeter in which a portion of the current is shunted around the thermal element, the same two effects can be present in the multiplier or shunt arrangement. In addition, there are likely to be inductance errors in the shunt or in the series resistance elements. These sources of error usually limit a thermal voltmeter to a maximum of 5000 to 10,000 cycles. By using a high-grade a-c. resistance coil for the multiplier, the frequency range of a voltmeter can be increased by a factor of two or more.

D-c. reversal differences ordinarily arise from a mislocation of the thermojunction on the heater element. These differences, if greater than about 0.1 percent of the measured quantity, prove very annoying when the instrument is used to measure direct current. In such measurements it is advisable to take the mean of values corresponding to the two directions of current.

The *temperature coefficient* in a thermocouple instrument can be as much as 0.2 percent per degree C. Errors of 1 percent or more can result from (1) a lack of temperature equilibrium between certain components (for example, the thermocouple and the moving coil) within the instrument, and (2) a failure to apply corrections to the pointer indications of the millivoltmeter if its temperature is different than the temperature at the time the scale was calibrated.

If one is to use a thermocouple instrument for accurate measurements the magnitude of the errors resulting from the first three sources must be known. They should be small, preferably less than 0.05 percent over the desired frequency range. To get this information, the instrument should be tested at the desired frequencies in a standardization laboratory.

The d-c. reversal differences can be determined by the user. To do this the direct current necessary to deflect the pointer to the desired scale position is measured by a potentiometer with accessories. The same measurement is made with the polarity reversed. If the difference between these two measurements is more than about 0.5 percent the thermoelement should be returned to the manufacturer for adjustment or replacement.

Transfer Principle

Even after precautions are taken to eliminate or to correct for the errors mentioned above, there exists the possibility of errors from (1) unsuspected temperature differences, (2) changes in the components of the indicating element, and (3) drifts that can occur in the thermoelement if the measured quantity is read directly from a calibrated scale. If measurements are to be made in the conventional

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Principles of

AUTOMATIC CONTROL

By R. E. ROGERS, JR.
The Foxboro Company

The four basic controller responses—two-position, proportional-position, reset, and derivative actions—and their pneumatic circuits are illustrated and described

THERE are four basic types of automatic-control systems, all of which have been in existence and use for nearly 15 years. The trend of design since World War II has been to improve measuring systems, to separate recorder and controller mechanisms, and to increase speeds of detection and correction of process deviations.

This discussion is confined to pneumatic-operated control mechanisms because they represent 90 percent of the control instruments being used today.

The basis for all types of pneumatic control systems is the double-orifice system (Fig. 1). Air from the supply passes through the first restriction and splits two ways. One line goes to a second restriction, which is a nozzle open to the atmosphere. The other line (the output) goes to a diaphragm motor or cylinder. With the nozzle open to atmosphere, air escapes from it faster than air can pass through the first restriction, and the air pressure in the output line falls to a low value. However, when the finger or "flapper" covers the nozzle, the output air pressure builds up until it equals the supply pressure. By adjusting the diameters of the two restrictions it is possible to use forces of inch-ounces on the flapper and have sufficient power to actuate a valve or operator.

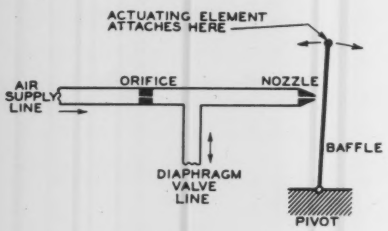

Fig. 1. The double orifice for converting flapper motion into pressure output.

This principle is used also to measure levels in tanks of liquids by placing the nozzle below the liquid surface and by mounting an indicating or recording level gage on the output line. It is being used also by at least one instrument manufacturer for a transmitter system. In general, however, this simple device has been abandoned because of its slowness of action. However, by inserting an air relay which supplies full air pressure to the operator almost instantly, we have a more useful tool. Fig. 2 shows a typical on-off controller with the double orifices and control relay. Any movement across the control point of the measuring element results in an immediate movement of the flapper across the nozzle, which causes the relay to throw from one position to the other. A movement of the measurement of ⅛ of 1 percent of its total scale travel is sufficient to operate the relay through its full stroke. This action is called two-position action.

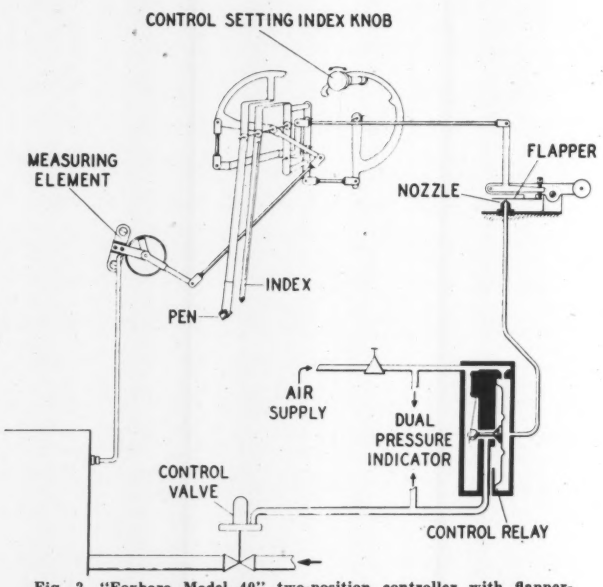

Fig. 2. "Foxboro Model 40" two-position controller with flapper-nozzle and control relay.

Two-position Action

The first basic system of automatic control is two-position action, which is the ASME term for this system; it is called "on-off" or "open-and-shut" action also.

Fig. 3 shows the response of a two-position controller. The curves show the change in controller output produced by a measurement change. Valve action occurs only when the measurement

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crosses the control point, and the valve operates from one extreme to the other. For all positions of the measurement above the control point the valve has one position; for all positions below the control point the valve has another position.

It follows, therefore, that the measurement and controller action of an on-off controller must be continually cycling. When applied to processes suited to this type of control the amplitudes of the cycles can be so small that the record can be considered a straight line. When the amplitude of the cycles becomes excessive, the on-off action must be changed to throttling action.

Application in Process Control

There are two general types of processes—batch and continuous. The two-position controller is the simplest of the controller types and is used widely in many industries. In the modern refinery, as in other continuous processes, its use is generally limited to emergency operation of valves and alarms because the more common refinery control problems require throttling action. However, two-position control is used widely in batch processes.

Batch processes still represent the majority of controller applications. They are usually difficult to control by hand but often require only the simplest type of automatic control. For example, a tank of water can be maintained at 120 deg. F. by opening a valve in a steam line when the temperature falls to 119 deg., and closing the valve when the temperature reads 120 deg. It is the high ratio between the btu. of heat in the tank and the btu. per minute we add that makes two-position control successful.

In general, it may be said that any process where the heat or volume stored is 100 times greater than the heat or volume which may be added in one minute through a control valve is suitable for two-position control without excessive cycling. Some examples are: (1) Domestic hot-water heater and domestic refrigerator, (2) domestic heating system, (3) canning retorts, (4) mixing kettles for food, (5) lumber dry kilns, and (6) feed-water heaters in power plants.

The Control Valve

As most controller applications deal with the flow of fluids—steam, gas, water, oil, air, etc.—the control valve is a necessary part of the circuit. In the two-position circuit, valves are usually globe type with single seat and diaphragm motor. The power movement is always in one direction and is opposed by a spring which must be strong enough to close the valve against friction and line pressures. When the difference in pressure across the valve requires a diaphragm motor of unreasonable size, the valve must have double seats which are partially balanced against high pressure-differentials. The valve used for two-position controllers has only to close and to open; it is not required to take any intermediate position.

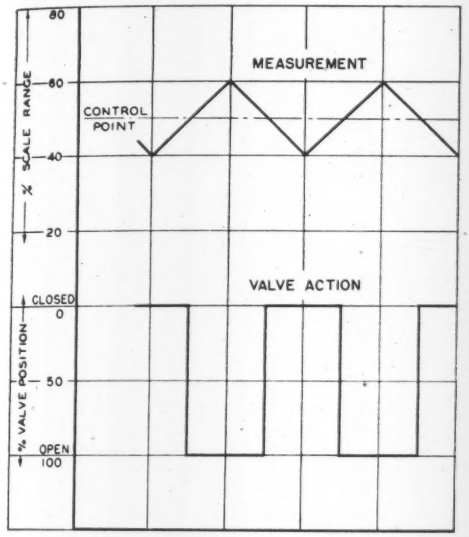

Fig. 3 (above). Response of a two-position controller.

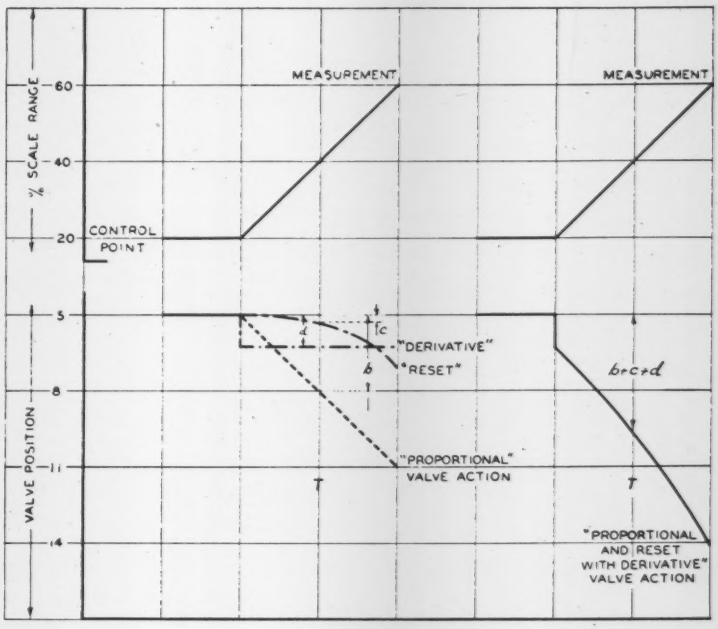

Fig. 4 (right). Curves showing proportional-position, reset, and derivative action; also the combined response.

PROPORTIONAL-POSITION ACTION

The second basic control system gives an output that is proportional to the change in the measurement, as shown by the dotted line in Fig. 4. The ASME calls this *proportional-position* action; it is known also as *throttling* or *modulating* action. A proportional-position controller is shown in Fig. 5. Note that the basic difference between Fig. 2 and Fig. 5 is the proportioning bellows, which repositions the flapper to give proportional control.

If the measuring element moves the flapper toward the nozzle, the relay throws and supply air is admitted to the proportional bellows until the bellows causes the flapper to move away from the nozzle, closing off the air supply to the proportioning bellows and returning the flapper to its original position. It follows that any movement of the measuring element (or control index) results in a proportional movement of the bellows. As the position of the bellows is proportional to the pressure in it, the pressure in the bellows (and the output) bears a fixed relation to the element position.

The *amount* of valve movement is directly proportional to the *amount* of measurement and is in a direction to oppose the deviation. The valve position always bears a fixed relation to the measurement, and the peak value in valve correction occurs at the point of greatest measurement deviation as long as the measurement does not move outside the proportional band of the controller.

Proportional Band

In most proportional-type controllers it is possible to vary the amount the valve moves for a given measurement change by adjusting the proportional band of the instrument. A 100-percent proportional-band controller is one where 100-percent scale movement of the measurement is required to give 100-percent valve movement—that is, the proportional band of a controller is defined as being the percentage of the scale through which the measurement must move in order to stroke the valve through its full travel.

Offset

One important fact about the proportional controller is that each valve position is related to a definite position of the measurement. Thus a controller may be adjusted so that the valve brings the measurement to the control index, but the measurement will be maintained at this point only as long as there is no change in either load or other conditions. If for example the pressure drop across the valve changes, then it must assume a new position in order to pass the original flow. Therefore, the measurement must move to a new position which necessarily will be away from the control point before equilibrium is reached again. This drift from control point with load or condition change is defined as *offset* in ASME terminology.

The design of pneumatic controllers is a science. Hydraulic and electronic analogs can be set up to grind out the proportional-band settings for processes with various time constants so that these settings can be predetermined. Unfortunately, no practical method has been found to accurately determine the time constants of actual continuous processes and it is necessary for the instrument engineer to use his experience to guide him. Of course, with modern instruments, the adjustment of proportional-band settings is as simple as rotating a dial, but the amount of offset is still an unknown result.

Control Valve

The control valve for proportional-position-action controllers must be better than a single-seat globe valve; diaphragm-type throttling valves are used. Valves are on the market whose characteristic flow curves are a straight line on semi-log paper when the vertical ordinates are percent of total flow and the horizontal ordinates are percent of total lift. This means that on an air-to-lift valve, the flow increases about 40 percent for each 1-lb. increase in diaphragm pressure; in other words, equal increase in pressure gives equal *percentage* increase in flow. This *equal-percentage* characteristic can be produced by modified V-port or parabolic valve-plungers, and are used widely with proportional-type controllers.

Application

Certain rules of thumb are available for applying proportional-position-action controllers. These controllers do not produce good results on applications easily handled by two-position controllers because of the wide bands required. They are satisfactory as pressure controllers on gases and vapors because band settings rarely exceed 10 percent and the offset is small. Pressure controllers on liquids require 30 to 50 percent bands; pump discharge governors require up to 100 percent. Temperature controllers require from 25 to 150 percent. Flow controllers require from 15 to 30 percent. Liquid-level controllers require 75 to 100 percent. Pneumatic transmission doubles these values. These figures indicate that many applications requiring throttling controllers also require proportional-band settings where appreciable offset may be expected. If this is satisfactory you need go no further. If exact control is required, however, you must use reset action to overcome the offset.

It is interesting to note that the proportional-position mechanism is used not only for controllers but also for pneumatic transmitters and valve-stem positioners. These always have 100-percent proportional band.

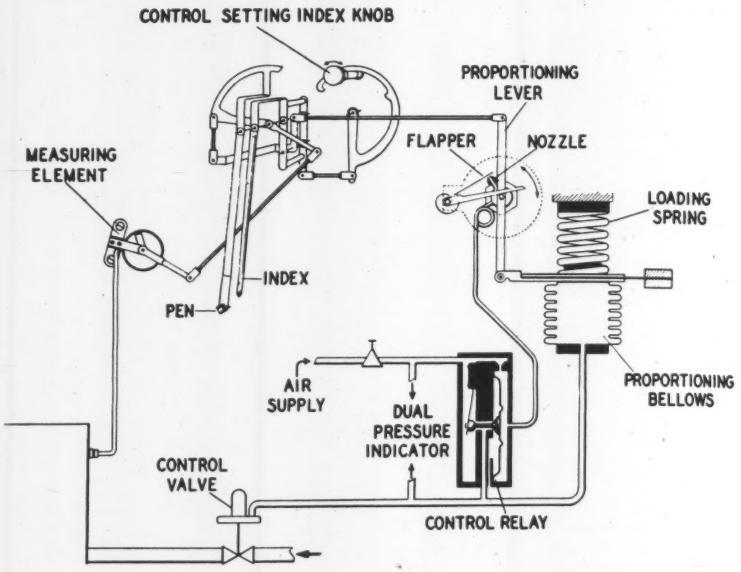

Fig. 5. "Foxboro Model 40" proportional controller.

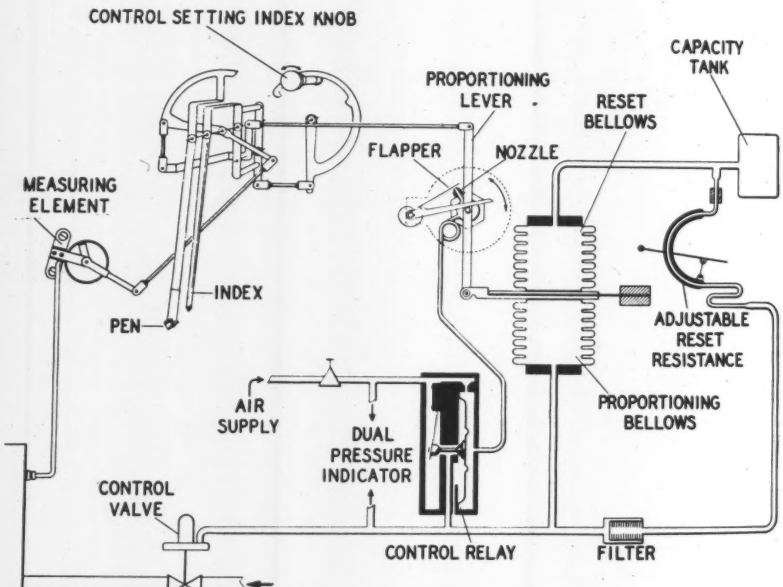

Fig. 6. "Foxboro Model-40 Stabilog" controller with proportional plus reset actions.

RESET

The third basic control action is reset action. It is almost always used in conjunction with proportional-position action, so that the controller provides proportion-plus-reset control.

A precise definition of reset is given by the ASME, which lists two different types called (1) *constant-speed-floating* and (2) *proportional-speed-floating*. The constant-speed-floating controller is one which produces a *fixed rate* of valve action in a direction to correct for the measurement deviation. Regardless of the amount of deviation, the valve moves at a fixed rate until the

measurement is returned to the control point. The conventional controller, however, employs proportional-speed-floating action, which produces a valve rate proportional to the measurement deviation from the control point. Thus the term "reset" in the ensuing discussion refers to proportional-speed-floating action.

When the measurement is offset from the control point by a fixed amount, reset action causes the valve to move at a constant *rate*. If the deviation becomes greater, the rate of valve motion increases, as shown by the curve marked "reset" in Fig. 4.

Proportional plus Reset

Fig. 6 shows the reset circuit added to a proportioning circuit. The only change made is the substitution of a bellows for the loading spring. The proportioning action is exactly the same as in the proportional controller; however, the position of the bellows is now proportional to the difference in pressure between the two bellows. Note that the air line to the reset bellows is a variable orifice called "adjustable reset resistance."

The reset action occurs as long as the pressure in the reset bellows differs from that in the proportioning bellows. The ASME calls this proportional plus proportional-speed-floating action. It is commonly called *proportional-plus-reset* action in industrial control work. The curves in Fig. 4. show clearly that the correction applied by the proportional circuit depends only on the magnitude of the deviation; the amount of corrective action due to reset is governed both by the magnitude and (primarily) by the duration of deviation.

Derivative Action

Proportional and reset controllers were used for many years with success. As control requirements became more exacting, it was realized that there was a need for a further stabilizing influence in control—something that would give an "anticipatory" action. This led to the development of *derivative* action, which is the fourth type of control action.

Derivative action applies a correction proportional to the *rate* of measurement deviation, as shown in Fig. 4. When the rate of deviation is constant, the correction is a constant. It is unaffected by either the amount of deviation or the duration of deviation.

The derivative function always is used in connection with proportional-type controllers. Fig. 4 also shows the action that a controller with proportional, reset, and derivative actions would give for the measurement deviation shown. The correction is the sum of the three actions.

It is important to note that whereas proportional and reset functions produce a positive correction as long as the measurement is above the control point, derivative can produce a correction in the negative direction as soon as there is a reversal of motion of the measurement. Derivative can be said to be a purely stabilizing action. The addition of derivative to a controller causes the correction to be applied sooner than otherwise, and this is true whether the measurement is deviating from or toward the control point. It is this earlier application of the valve correction which is so valuable in controlling processes where there is difficulty of control caused by an unfavorable process characteristic.

A simple analogy describes the derivative function used in combination with the proportional action. Consider an automobile with its springs responding to the vertical motion of the wheels. Vertical motion of the wheels imparts a vertical motion to the car, but the extent of this motion depends on the strength of the springs. If the springs are made weak the vertical motion of the car will be small. However, there will be a tendency for oscillations to occur. The addition of shock absorbers removes these oscillations because shock absorbers respond only to the motion and not to the position of the car and are, therefore, derivative-type controllers. The combination of springs and shock absorbers gives a proportional and derivative effect.

When driving a car at a low speed along good roads there is no shock-absorber action at all. But there are few cars sold without shock absorbers, although many of them are used continually on smooth roads at only low speeds. The same comparison can be made in determining whether or not derivative should be used in the controller. Even though the process may be subjected to disturbances only occasionally, it is good practice to include the derivative function and insure best performance at all times.

Fig. 7 shows the derivative circuit added to the controller. The addition consists of a restriction between the relay and one part of the double proportional bellows.

Note that when a measurement *change* is taking place, the output pressure of the derivative controller is equal to that of the proportional type plus or minus the pressure drop across the derivative resistance. This derivative effect can be varied by (1) changing the value of the derivative resistance and (2) altering the volume of the bellows and/or capacity tank. It is customary to determine (2) during manufacture and to provide an adjustment of (1) for selection of the optimum value of the derivative in operation.

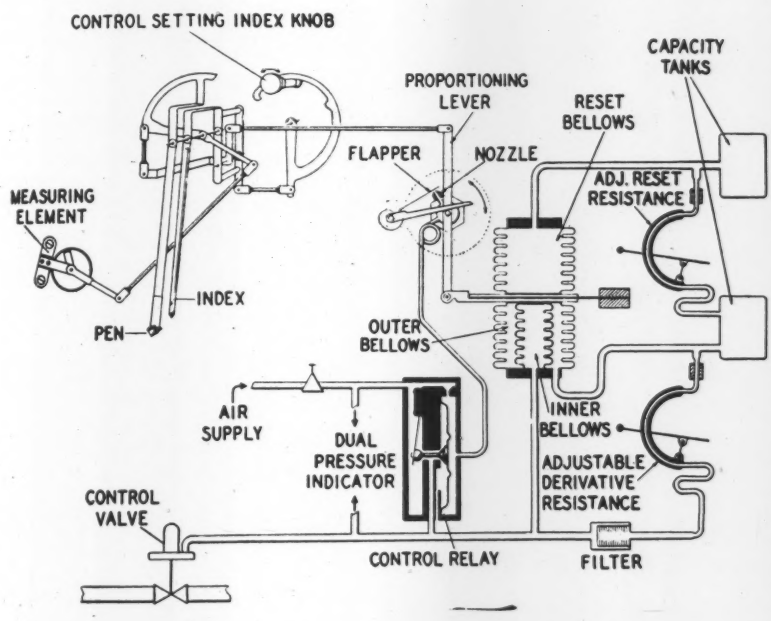

Fig. 7. "Foxboro Model-40 Hyper-reset Controller" with proportional, reset, and derivative actions.

Adjustment Resistances

The derivative and reset adjustment resistances present a new conception of adjustable resistances in pneumatic controllers. This new arrangement consists of a Bourdon tube of small cross-sectional area, one end of which is fixed and the other end positioned by moving a lever. As the lever moves, the cross-sectional area changes considerably and alters the resistance to air flow. It is possible to produce units with a rangeability of 500 to 1 and with an accurately calibrated scale in the desired units.

BISMUTH Thermocouples

By ALVIN B. KAUFMAN
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Availability of ductile bismuth and bismuth-alloy thermocouple wire has opened new vistas in temperature measurement in below-zero range

Fig. 1. Testing thermocouple response to strong magnetic fields.

UNTIL the presentation of ductile bismuth and bismuth-alloy thermocouple wire to the trade (by Fitzpatrick Electric Supply Co., 444 Irwin St., Muskegon, Michigan) this year, bismuth has been more of a textbook item than a practicality because bismuth wire was brittle and with age became even more so, cost was high, and bismuth-alloy wire was not available. Now that it is available in useful form, however, it is opening new vistas for temperature measurement, particularly in the below-zero range.

Properties

Interest in bismuth thermocouples was stimulated because of all ductile metals it has (1) the greatest resistance change with temperature, (2) it has the lowest thermal capacity of all metals, which makes it a most ideal metal for thermocouples where rapid response is required, (3) it has the least thermal conductivity of all pure ductile metals, (4) it has *the highest* negative thermocouple voltage per degree change in temperature, (5) alloy "B", developed by Fitzpatrick, has the highest positive thermocouple voltage of ductile metals, and (6) it can now be supplied in ductile wire, rod, ribbon, or sheets that can be bent over fairly sharp radius.

Bismuth has other electrical qualities that affect its use. Bismuth wire has a great change of resistance when subjected to a magnetic field or to change of temperature, and it has the highest Hall coefficient for ductile metals. These factors generally limit the use of bismuth thermocouples to manual- or automatic-balancing potentiometers.

The use of a direct-reading meter is not indicated because the wide variation of lead resistance would affect accuracy of calibration unless the leads are maintained at ambient or hot-junction temperature, or unless each specific installation is calibrated individually. The use of the wire for resistance-bulb pyrometry is limited to locations not involving d-c. magnetic fields of much over earth's constant. Its great Hall-effect coefficient indicates a possible response of the thermocouple to strong magnetic fields, although tests conducted by the author with a 2500-gauss magnetic field (Fig. 1) showed no error from this source.

Uses

As bismuth is the most sensitive metal known for use in thermocouples, it has been used for astronomical uses, along with bolometers of various types, and for other experimental purposes.

In large gage sizes built into thermopiles, its output can be used to operate holding coils and other mechanisms. Such a thermopile can be used also for direct application to the grid of tube amplifiers or thyratron-controlled power sources.

Before proceeding further it must be noted that other thermocouple materials are capable of much greater thermoelectric output than bismuth because of their ability to withstand much higher temperatures. Bismuth excels these materials only within its operating range. It allows the generation of high potentials at *low temperatures*. This can be seen on Fig. 2.

A stable alloy "B" was developed as the companion for ductile bismuth. This combination gives an output of 0.04088 millivolts per degree Fahrenheit from −114 deg. F. to +350 deg. F. (its top range); spot checks show the line continues to liquid-air temperature of −424 deg. F. This gives by far the largest output, the only uniform output known, and a straight line with no calibration for bracket ranges!

Bismuth can absorb in itself only one-third the heat that copper does, and transmits that heat 1/80th as fast as copper. Because its capacity and conduction of heat is so low, its response is practically instantaneous.

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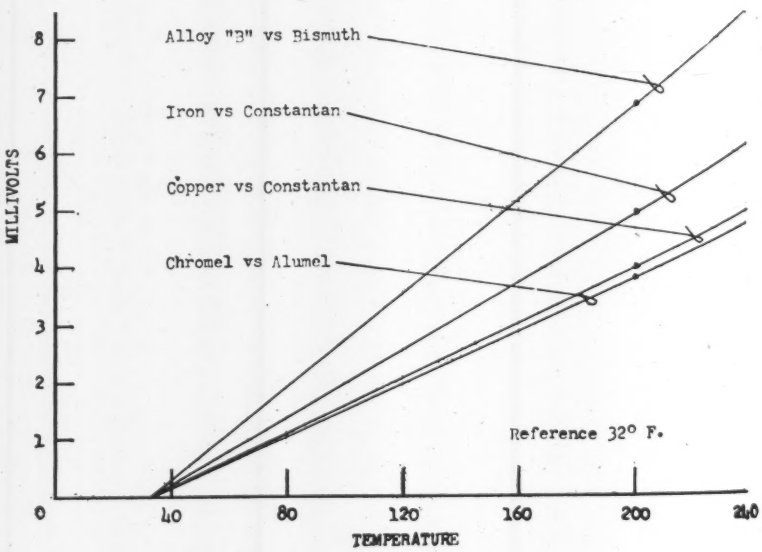

Fig. 2. Response of various thermocouples.

SMOKE Measurement

By CHARLES T. FOY
Berkley E/E Company

Industrial smoke represents not only loss of money but also poor public relations

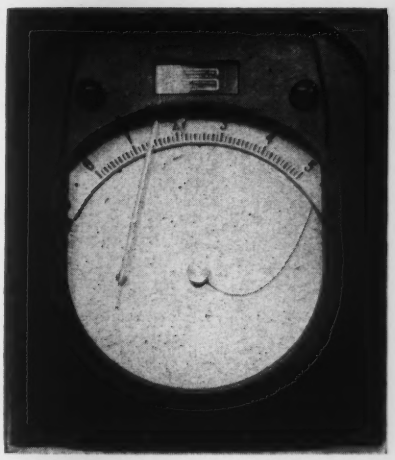

Fig. 1. Chart of smoke meter, showing Ringlemann numbers.

SMOKE is simply finely-dispersed, unburned carbon suspended in flue gas. It is formed when fuels such as coal, oil, and wood are burned without sufficient oxygen for complete combustion. Smoke is seldom a problem when gas is used as a fuel, thus this article applies only to oil, coal, or wood firing.

Objections to Smoke

There are two reasons why we do not want smoke coming out of the stacks in our plants. First, it costs money. A smoking stack means loss of part of our fuel up the stack in the form of unburned carbon. For every pound of carbon formed, 94,000 btu.'s are lost. This unburned carbon further reduces combustion efficiency by depositing itself on tubes of the boiler or heater, which materially reduces the rate of heat transfer from the hot flue gas to the fluid being heated.

The second reason why smoke is objectionable is that laws have been enacted recently in many communities, making it an offense to discharge smoke over more than a two-minute period.

Units and Measurement

The unit of measurement is the *Ringlemann number*. Ringlemann numbers form an arbitrary scale from zero to five (Fig. 1). Ringlemann 0 indicates complete absence of smoke, #1 a light haze, and so on through #5 for dense black smoke. Ringlemann 2 is the point at which smoke-abatement people start to hand out citations.

If combustion efficiency is plotted vs. smoke density, it is found that a smoke density of Ringlemann 1 corresponds to maximum combustion efficiency. It is interesting to note that this is true whether the fuel is coal, oil, or wood, and that fuels of different analyses have no effect on this relationship. Therefore it follows that smoke-density meters can be used effectively as combustion meters in plants that burn a variety of fuel oils.

Instrument Components

A smoke, or combustion, meter consists of three parts—a light source, a photoelectric cell or other light-sensitive element, and an indicating or recording unit. The photoelectric cell is used most commonly. A photocell is simply a vacuum tube in which light-sensitive metals are used. Current passing through the photocell varies with the amount of light received by the tube. Therefore a light source is mounted on one side of the smoke passage, and the photocell is mounted on the other side, directly opposite the light source (Fig. 2).

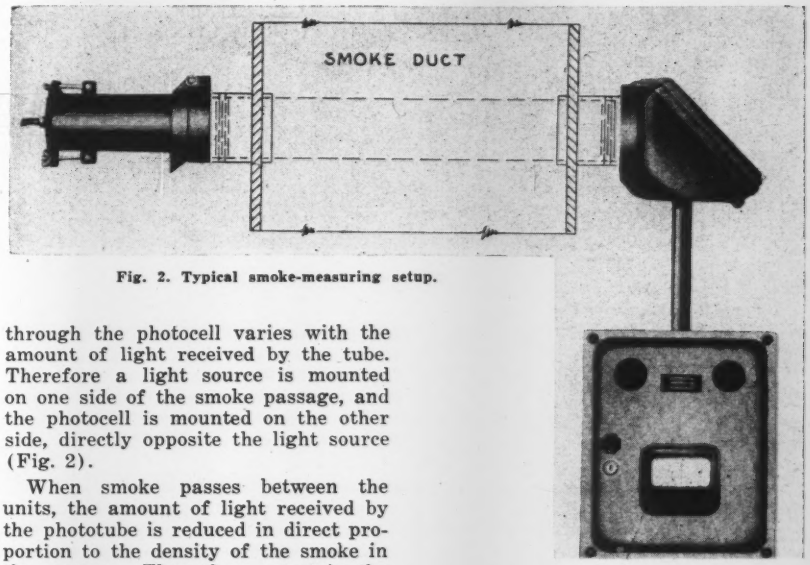

Fig. 2. Typical smoke-measuring setup.

When smoke passes between the units, the amount of light received by the phototube is reduced in direct proportion to the density of the smoke in the passage. Thus the current in the circuit also is reduced proportionately. This current is amplified and measured by an ordinary milliammeter calibrated in units of smoke density. Relays usually are incorporated in the circuit to sound alarms at predetermined densities.

Two types of recorders are available at the present time. One type draws a continuous straight line on a circular chart. If smoke exceeds a preset amount, the pen moves upward and draws another straight line, continuing until the density decreases to normal, when the pen returns to its former position. This recorder reports only time and duration of excessive smoke, but does not show smoke density.

Practical Factors

The following points should be considered when purchasing a meter of this kind. It should be noted whether or not the unit under consideration has a wide light beam. This is important because meters with wide light beams are not affected by expansion and contraction of stacks or breechings. Alignment of stack units becomes critical when meters with narrow light beams are used. It should be noted also that no special wiring or coaxial cable is required to make an installation; and the stack units should be hinged in a manner which allows for easy lens cleaning.

Maintenance of smoke-density meters is no problem provided a proper installation is made. The principal problem is keeping the lenses clean. The cleaning periods vary from once a week to once in several months, depending on the installation. Maintenance can be reduced greatly if a number of small holes are drilled in the mounting between the lens and the duct, provided a negative pressure exists inside the duct. If there is positive pressure, an air purge line connected at this point is most helpful.

*Presented at the Los Angeles Harbor Junior College "Instrument Maintenance Short Course," Nov. 15-17, 1951.

A DATA-PLOTTING MACHINE

By VERNON H. BAKER, Research Associate Professor, and BUFORD M. CANNON, Graduate Fellow
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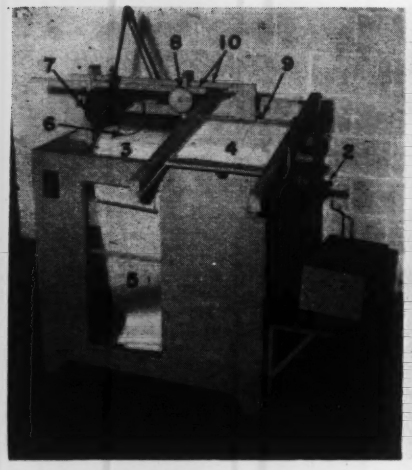

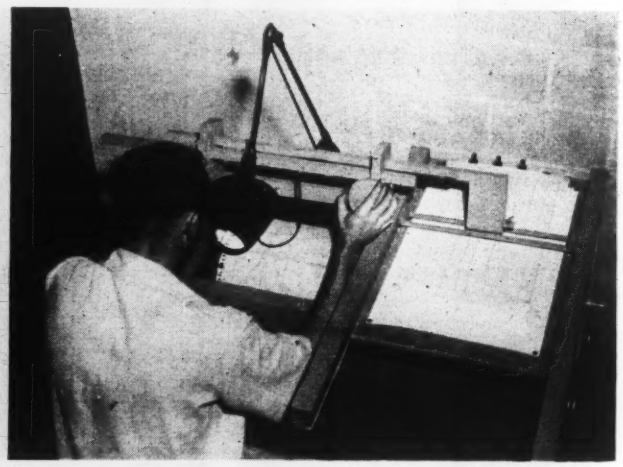

Fig. 1 (left). The plotting machine: 1, motor and gear reduction; 2, drum drive shaft; 3, drum; 4, plotting table; 5, chart; 6, guide point; 7, magnifying glass; 8, hand control; 9, plotting pen; 10, plotting arms.

Fig. 2 (right). Operator plotting curves. Note the small wire between the arms that support the guide point. This wire will enable the operator to anticipate the location of the next point to be plotted.

THE multiple-point temperature-recording potentiometer has become a popular research instrument for recording temperatures. It often is desirable in research and test work to have the chart data plotted on coordinate paper, and instruments that plot and record data from specific problems have been reported by Keinath[1] and Loucks.[2,3] In some of the research work in processing agricultural products at the Virginia Polytechnic Institute, it was desirable to transfer data from a 16-point recording potentiometer chart[4] to coordinate paper. Although this probably could have been accomplished with commercially available equipment, it was desirable to perform the plotting operation without purchasing any additional equipment because a 16-point multiple-printing recorder was available.

Tests conducted by engineers at the Virginia Polytechnic Institute show that about 1 to 1.5 man-hours are required to transfer and plot a 24-hour thermocouple record from a potentiometer chart to coordinate paper. This represents considerable effort when 16 different points are to be plotted.

Model 4 of a plotting machine that transfers the data from a potentiometer chart to coordinate paper in the form of a curve has been reported.[5] Model 5 of this machine (Fig. 1) plots curves at the rate of 3 ft. or more of recorder chart per minute. With this machine it takes about 8 minutes to plot the records from one thermocouple for a 70-hour test if the chart on the recording potentiometer is operated at a rate of 4 inches per hour.

Without the use of the plotting machine, an operator would normally require at least 2 man-hours to plot the record of one thermocouple that prints every 8 minutes for the 70-hour test. This procedure saves considerable time and, in addition, the use of the machine eliminates much of the drudgery of the hand-plotting operation.

The machine (Fig. 1) operates as follows: An electric motor is connected to the drum drive (2) through a gear-reduction system (1). As the drum (3) turns, a pinion gear on the drive shaft through the drum meshes with a rack gear that is fastened to the plotting table (4). As the chart (5) moves over the drum, the operator follows the point to be plotted with a guide point (6) by observing through the magnifying glass (7). The guide point is adjusted laterally with the hand control (8). The horizontal motion of the guide point is transferred to the plotting pen (9) through the plotting arms (10). The chart is placed over the drum and is fastened together as an endless belt. When the records for one point of the potentiometer have been plotted, it is only necessary to re-orientate the machine and continue by plotting the records for the next point.

The accuracy of the data when transferred from the −50 to +300 deg. F potentiometer chart to coordinate paper has proven to be plus or minus one deg. F. The final accuracy on the transfer operation depends on the skill of the operator and the amount the paper chart has expanded or contracted.

This plotting machine transfers data recorded on a multiple-printing recorder chart to convenient-size coordinate paper for better analysis of maximum and minimum points, slope, and other pertinent data.

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(4) Jordan, A. H. and Vogelsang, C. A., "Application of Multiple Printing Recorders," *Instruments*, June 1946, page 339.

(5) Earp, U. F. and Baker, V. H., "A Plotting Machine For The Multiple-Point Potentiometer Chart," *Agricultural Engineering*, Feb. 1951, page 101.

INSTRUMENT ELECTRONICS

Basic oscillation circuits include the tickler coil, Hartley, Colpitts, tuned-plate tuned grid, ultraudion, electron-coupled, crystal-controlled, tuning-fork, magnetostriction, dynatron, transitron, phase-shift, Wien-bridge, sawtooth generator, multivibrator, Eccles-Jordan, beat-frequency, shock-excited, Klystron, and magnetron oscillators — a total of twenty, all worth knowing.

By MILTON H. ARONSON
Technical Editor, *Instruments*

X. OSCILLATOR CIRCUITS

BASIC electron-tube functions are rectification, amplification, and oscillation. Oscillator circuits produce alternating waveforms of various shapes, the most common being the sine wave, the square wave, and the sawtooth wave.

The *sine wave* is the most common and most useful waveform in electronic circuitry. It is a basic waveform in that all other wave shapes are composed of sine waves of various frequencies and phase relations (see Chapter 4). The sine wave is used to test circuits, to energize bridge circuits, to change the frequency of signals by heterodyning, to measure frequency by comparison, to act as a radio-frequency carrier of information, to develop high-power ultrasonic vibrations in fluids, and to heat articles by dielectric and induction heating. Most oscillator circuits with resonant elements produce sine waves.

The *square wave* is used in triggering, timing, and gating (selective timing) applications. It is developed by the multivibrator, or square-wave generator.

The *sawtooth wave* is used in sweep circuits to drive the visible spot across the face of cathode-ray oscilloscopes and radar indicators. It is developed by relaxation oscillators, or sawtooth generators.

Types of Oscillation

Circuits with Resonant Devices

There are two basic types of oscillators—those that use a resonant device and those that do not use a resonant device. A resonant device is one in which energy is transferred between elements in such a way that it oscillates back and forth continuously. For example, a swing or pendulum is a naturally resonant device because energy is alternated between kinetic and potential forms. A mass and a spring are resonant for the same reason. Owing to the nature of the interchange of energy, the swing or pendulum tends to swing forever when once set into motion; of course energy losses eventually stop the oscillation.

As explained in Chapter 3, a parallel-resonant *L-C* circuit, or *tank*, is naturally resonant. When circulating current begins to flow in the tank, it tends to oscillate continuously because energy is stored first in the dielectric of the capacitor and then in the magnetic field of the inductor, each flowing into the other on alternate half cycles of the oscillation.

In order to keep any resonant element oscillating it is necessary to add only enough energy to the circuit to offset the loss of energy in the circuit. For example, a swing need be pushed only enough to offset losses due to friction and wind resistance. Similarly, a parallel-resonant *L-C* circuit need be given only enough energy to offset losses due to resistance and radiation. As a loss-free resonant element is impossible to obtain (the best bearing has some friction, the best high-Q inductor has some resistance), every oscillator requires energy addition from an external source. As an efficient resonant element loses little energy, only small amounts of energy need be supplied to a resonant element to sustain oscillation in the element.

Circuits without Resonant Devices

The second type of oscillator does not use a resonant element; it is simply an amplifier with feedback from output to input. If part of the output of any amplifier system is fed back into the input, the "closed-loop" system can oscillate provided (1) the feedback signal is *in phase* with the input signal (measured without feedback) and (2) the amplitude of the feedback signal equals the input signal (without feedback). Any closed-loop system—that is, one with feedback from output to input—becomes resonant at the frequency at which the feedback signal has the same amplitude and phase as the input signal (without feedback). When these two conditions occur, the feedback signal alone keeps the system oscillating.

Oscillation in systems without resonant elements often occurs because the output of any amplifier lags the input as the frequency of the input is raised. Thus, there usually is one frequency at which the ouput lags by 360 degrees—that is, the output is again in phase with the input. If the amplifier gain at this frequency is such that a feedback signal equals the input signal, the system oscillates sinoidally. This principle is important in closed-loop servomechanisms and in resistance-capacitance oscillators, as will be described.

To summarize the conditions under which systems oscillate—(1) the system with a resonant element oscillates when the small energy losses in the resonant element are replaced in proper phase and amplitude, and (2) the system without a resonant element oscillates when amplified output energy is fed back into the input in proper phase and amplitude. In both types the phase of the feedback signal must be the same as that of the input signal—that is, it must "push" the oscillator or system in the same direction that the system is moving.

The oscillator with a resonant element requires much less feedback signal and can be made very stable by choice of resonant element. The types of resonant elements used in electronic oscillators of this type are (1) parallel-resonant *L-C* circuits, including butterfly tanks and resonant cavities, (2) piezoelectric crystals, (3) tuning forks, and (4) magnetostriction rods.

Tickler-coil Oscillator

One of the simplest oscillator circuits is the tickler-coil oscillator, shown in Fig. 10-1. The resonant tank is inductor *L* and capacitor *C* in parallel. As the natural resonant

ANSWERS TO QUIZ IX.—SOLID-STATE AMPLIFIERS

9-1. (c)	9-6. (a)	9-11. (c)	9-16. (a)
9-2. (b)	9-7. (d)	9-12. (d)	9-17. (c)
9-3. (b)	9-8. (a)	9-13. (d)	9-18. (d)
9-4. (a)	9-9. (c)	9-14. (a)	9-19. (a)
9-5. (c)	9-10. (b)	9-15. (c)	9-20. (c)

Test items for X.—Page 794

frequency of the tank is $1/2\pi\sqrt{LC}$, the capacitor or inductor can be made variable so that the resonant frequency is adjustable. The capacitor usually is made variable. The C_G and R network provides grid-leak bias, which is used in almost all oscillators because it enables the oscillator to start oscillating easily and then provides stable bias.

When the oscillator is first turned on there is a surge of current that excites the tank. This signal is amplified by the amplifier. Tickler coil L_P is wound and placed so that a small amount of signal is inductively fed back into the tank; the coupling coefficient is represented by M. The feedback signal is of the proper polarity and amplitude to sustain a pure sinoidal oscillation.

The oscillator output can be fed to any desired circuit by either a connection to the tank or by another coil brought near the tank. This type oscillator is used widely in radio receivers as a *local oscillator* for heterodyning radio-frequency signals to a lower, or intermediate, frequency.

Hartley Oscillator

The Hartley oscillator (Fig. 10-2) is similar in principle and operation to the tickler-coil oscillator, except that one tapped inductor is used. A positive signal surge at the grid causes plate current to increase. The current flows up through L_P, causing the tap on L_P to become more positive than the bottom. This in turn induces a more positive signal at the top of L. As a positive signal at the grid results in a more positive feedback signal at the grid, oscillation is sustained.

Colpitts Oscillator

The Colpitts oscillator (Fig. 10-3) is similar to the Hartley, except that a pair of capacitors, C_1 and C_2, replace the tapped coil. The circuit action is similar in all other respects because the capacitors produce an effective tap on the coil. The inductance usually is varied for tuning, although capacitors C_1 and C_2 can be ganged and varied for tuning. The radio-frequency choke (RFC) is used in all oscillators to block the oscillations from the power source.

Tuned-plate Tuned-grid Oscillator

The tuned-plate tuned-grid oscillator (Fig. 10-4) has a tuned circuit in both the grid and the plate circuits. The feedback from plate to grid occurs through the small interelectrode capacitance. As the plate signal is 180 degrees out of phase with the grid signal, there must be another 180-degree phase shift in the feedback signal in order to produce oscillation. This occurs because the tanks are tuned to a frequency that is slightly higher than the oscillation frequency. Thus the tank is more inductive than capacitive. When current is fed through a tiny capacitor to an inductor, the voltage developed across the inductor is shifted in phase by 180 degrees. This shift makes the feedback signal in phase with the grid signal, thus sustaining oscillation.

Fig. 10-5 ilustrates the phase relations. E_G is the grid signal. This produces E_P, the plate signal. E_P produces I_C, the feedback current through the interelectrode capacitance. As the interelectrode capacitance is in series with the inductive tank, the current through the tank (I_L) is the same as I_C. However, a current through an inductor lags the voltage across the inductor by 90 degrees. Therefore I_L produces feedback signal E_L, which is in phase with E_G and thus sustains oscillation.

For this to occur, the grid tank must be inductive (tuned to a frequency higher than the resonant frequency) and the reactance of the feedback interelectrode capacitance must be higher than the reactance of the tank. As only the small interelectrode capacitance is used for feedback, both conditions are true and the circuit oscillates.

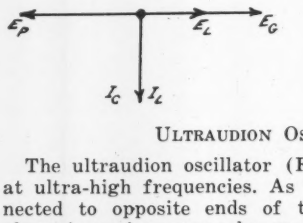


Fig. 10-5. Phase relations showing how the plate signal of a tuned-plate tuned-grid oscillator is shifted 180 degrees during feedback to the grid.

Ultraudion Oscillator

The ultraudion oscillator (Fig. 10-6) is used frequently at ultra-high frequencies. As the grid and plate are connected to opposite ends of the tank circuit, 180-degree phase inversion occurs because the opposite ends of a coil are always at opposite polarities—when one end goes positive, the other goes negative. However, this is true only when a point on the coil is grounded or kept at a fixed potential. This occurs in the ultraudion because the grid-cathode and plate-cathode capacitances act like the two capacitors in the Colpitts oscillator, effectively tapping and grounding a point on the coil. Capacitors C_2 and C_3 block the plate current from the tank, but pass r-f. oscillations with negligible reactance. Grid-leak bias is developed across resistor R_G.

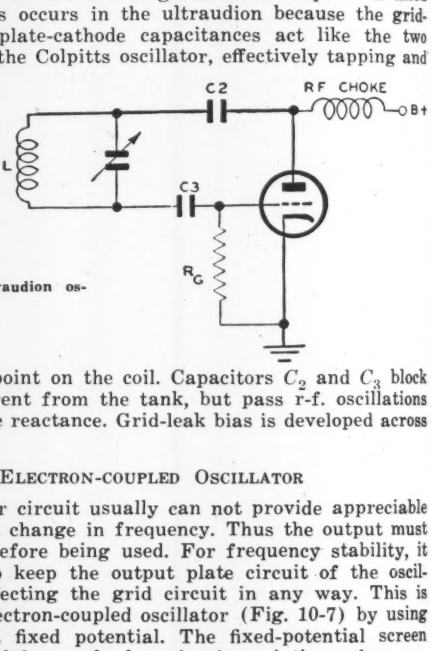


Fig. 10-6. Ultraudion oscillator.

Electron-coupled Oscillator

An oscillator circuit usually can not provide appreciable power without change in frequency. Thus the output must be amplified before being used. For frequency stability, it is desirable to keep the output plate circuit of the oscillator from affecting the grid circuit in any way. This is done in the electron-coupled oscillator (Fig. 10-7) by using a screen at a fixed potential. The fixed-potential screen shields the grid from r-f. plate-circuit variations, thus permitting stable grid-circuit action. The name "electron-coupled" arises from the fact that the only coupling between plate and grid circuits is by the plate-current beam of electrons. The oscillator thus is a combined Hartley oscillator and amplifier. Load variations (changes in power output) do not affect the frequency, as they would if there were coupling between plate and grid circuits.

Another advantage of the electron-coupled oscillator is that changes in screen potential affect the frequency opposite to the way that changes in plate potential do. Thus the circuit can be made independent of supply-voltage variations.

Fig. 10-1 (left). Tickler-coil oscillator. Fig. 10-2 (right). Hartley oscillator.

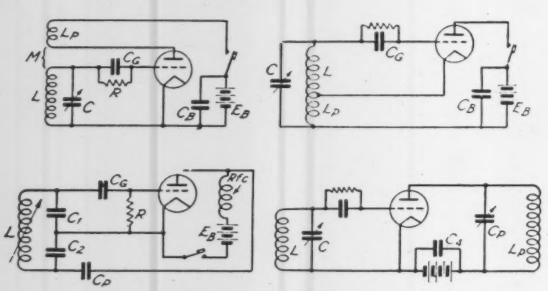
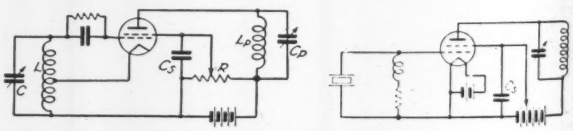


Fig. 10-3 (left). Colpitts oscillator. Fig. 10-4 (right). Tuned-plate tuned-grid oscillator.

Fig. 10-7 (left). Electron-coupled oscillator. Fig. 10-8 (right). Crystal-controlled oscillator using tetrode.



The electron-coupled circuit can be used as a *frequency multiplier* by tuning the plate tank to a harmonic of the natural resonant frequency of the grid tank. The grid tank then resonates at its fundamental frequency, but the plate tank oscillates at the harmonic frequency.

Crystal-controlled Oscillators

Oscillators that use resonant *L-C* tanks change frequency with change in load, supply voltage, or ambient temperature. Even the stability of electron-coupled oscillators is not high enough for many applications. Where the frequency must be highly stable, a *piezoelectric crystal* is used as the resonant tank, as shown in Fig. 10-8. The circuit is a tuned-plate tuned-grid oscillator. The resistor in the grid circuit is a grid-leak-bias resistor; the inductor is simply a radio-frequency choke.

The crystal is a substance (such as quartz, Rochelle salt, or tourmaline) which develops a charge across its faces when subjected to forces of compression or tension. Conversely, when connected to a source of potential, the crystal changes shape. The relation between mechanical and electrical effects is called *piezoelectric effect*. Quartz is used most often in crystal-controlled oscillators.

The mechanical-electrical properties of piezoelectric crystals enable them to oscillate with little energy loss and with high frequency-stability. As the oscillating crystal is a mechanical oscillator with mass, elasticity, and internal friction, the frequency of oscillation depends on the mass, elasticity, and dimensions, particularly the thickness. Although the thickness can be ground down to increase the resonant frequency, the frequency can not be decreased by grinding because the natural resonant frequency increases as thickness decreases. The thinness determines the upper limit at which crystals are usable; crystal frequencies are normally from ultrasonic frequencies to about 100 Mc. Of course, the crystal-controlled oscillator can produce only frequencies that are the same or harmonics of the natural frequency of the crystals used in the circuit.

The power obtainable is limited at high frequencies (megacycles per sec.) by the heat developed inside the crystal, and at low frequencies by the large amplitudes of vibration, which can crack the crystal. The amplitude of vibration depends on the amount of signal fed back into the grid circuit; the small amount fed back across the small plate-grid capacitance of a tetrode is sufficient to sustain oscillation.

As the crystal is a mechanical oscillator, the crystal holder must add as little damping as possible to the vibration. The crystal can be operated in a temperature-controlled holder to obtain a stability of 10 parts in a million. Stability of one part in 10 million can be obtained by temperature control of the entire circuit and by use of all possible precautions.

Tuning-fork Oscillator

The tuning-fork oscillator (Fig. 10-9), like the crystal oscillator, is a stable electromechanical resonator. The frequency is determined by the resonant frequency of the fork. Whereas crystal-controlled oscillators can operate from ultrasonic to high radio frequencies, the tuning-fork oscillator is used as an audio-frequency oscillator, usually developing 400, 440, or 1000 cps. They are characterized by good sinoidal waveform and frequency stability of about one part in a thousand.

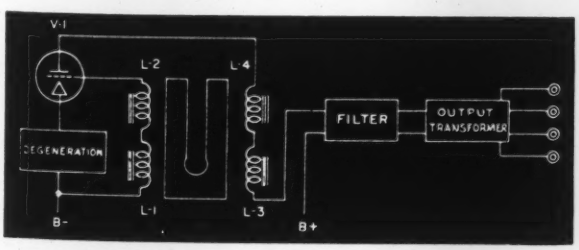


Fig. 10-9. Tuning-fork oscillator of General Radio Co.

Magnetostriction Oscillator

Some metals, such as nickel and nickel alloys, change shape when placed in a magnetic field. Also, when they are forced by mechanical means to shrink or expand, they change the magnetic field they are in. This effect is called magnetostriction.

A magnetostriction oscillator is shown in Fig. 10-10. The circuit is similar to a Hartley oscillator, except that grid and plate coils L_1 and L_2 are arranged to *prevent* feedback. Thus no oscillation can occur until the magnetostrictive rod is inserted in the coils. When the resonant frequency of the resonant tank (C, L_1, and L_2) is near the mechanical resonant frequency of vibration of the bar, a mechanical oscillation is produced in the bar. Frequencies of from several hundred cycles per second to several hundred kilocycles per second can be produced in this manner. This is a source of ultrasonic energy for industrial and military (sonar) applications. The term "transducer" was first applied to piezoelectric and magnetostriction oscillators used to produce high-energy ultrasonic waves for underwater sonar (sound navigation and ranging) applications.

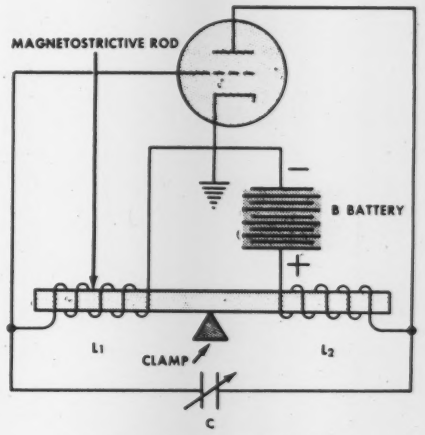


Fig. 10-10. Magnetostriction oscillator.

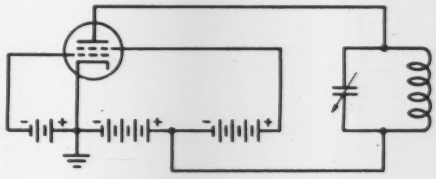


Fig. 10-11. Dynatron oscillator.

Negative-resistance Oscillators

In all oscillators, energy is fed back into the circuit to overcome losses in the circuit. As losses occur mainly because of resistance, the energy fed back can be considered a form of negative resistance that cancels the real, or positive, resistance in the circuit.

If the voltage across and the current through a resistor are plotted, the graph is a straight line with positive slope. Several devices show a negative slope when their voltage-current characteristic is plotted in this manner. For example, the plate characteristic of a tetrode has a region of negative resistance, as shown in Fig. 5-12 in Chapter 5. Any device that has a negative-resistance characteristic can be used to cancel real resistance and thus sustain oscillation in an oscillator.

Dynatron Oscillator

Fig. 10-11 shows how the tetrode is used as a *dynatron* oscillator. The resonant tank is connected to the plate. As the screen is at a higher potential than the plate, secondary-

emission electrons cause the plate current to *decrease* when plate voltage increases. This negative-resistance characteristic sustains the oscillation. The dynatron is simple, can be used from low audio frequencies to about 15 Mc., and has high stability and good waveform. The disadvantages are low power output and variation in "negative-resistance" tube characteristic with age of tube and between tubes of the same type.

Transitron Oscillator

The transitron oscillator (Fig. 10-12) uses a pentode with the screen grid coupled to the suppressor. As in the dynatron, the screen is at a higher potential than the plate. When screen potential is increased, it is found that there is a region in which screen current decreases because the negative suppressor repels fewer electrons to the screen.

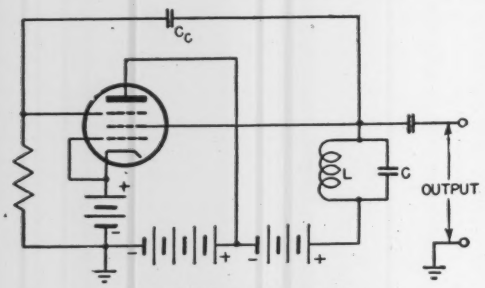


Fig. 10-12. Transitron oscillator.

The tube is operated in this negative-resistance region and the resonant tank is connected to the screen.

The transitron, like the dynatron, is a low-power device. However, as it does not use secondary emission as an operating principle, it is more stable than the dynatron; its frequency stability is comparable to that of a crystal oscillator without temperature control. Another advantage is a wide frequency range; it is used from low audio frequencies to above 60 Mc.

Resistance-Capacitance Oscillators

A resonant device was used in all the oscillators described. However, any amplifier can be made to oscillate by feeding output energy into the input if the signal fed back has (1) the same polarity as the signal without feedback and (2) the same amplitude as the signal without feedback. This type of self oscillation often is encountered in all "closed-loop" systems, such as servomechanisms, controllers, etc. There may be no resonant element because oscillation is not desired; however, whenever the two conditions are met, oscillation occurs whether it is desired or not. This principle is used in resistance-capacitance oscillators, which use *R-C* circuits to produce the phase inversion required to make the feedback signal the same polarity as the input signal.

Phase-shift Oscillator

Fig. 10-13 shows an amplifier with a 3-section *R-C* network between plate and grid. Each section produces a 60-degree phase shift in signal. Thus the phase shifter produces a 180-degree change in phase. As the plate signal is 180 degrees out of phase with the grid signal, the total phase shift is 360 degrees and oscillation occurs.

The oscillation occurs only at the one frequency at which the 360-degree phase shift occurs. The frequency can be changed by altering any of the resistors or capacitors in the phase-shift network. The circuit is characterized by good sinoidal waveform and high frequency-stability when small oscillations are produced. It is used in audio-frequency signal generators because it is tunable over a wide range of audio frequencies and because parallel-resonant *L-C* tanks become too bulky at audio frequencies.

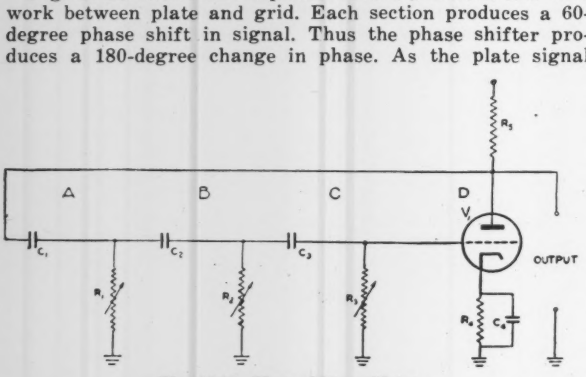


Fig. 10-13. Phase-shift oscillator.

Wien-bridge Oscillator

In the Wien-bridge oscillator (Fig. 10-14) a frequency-selective Wien bridge is used to select only one frequency for feedback. As two amplifier stages are used, the feedback signal from the plate of the second tube is in phase with the grid signal of the first tube and, therefore, oscillation at any frequency can occur. However, the bridge circuit selects only one frequency.

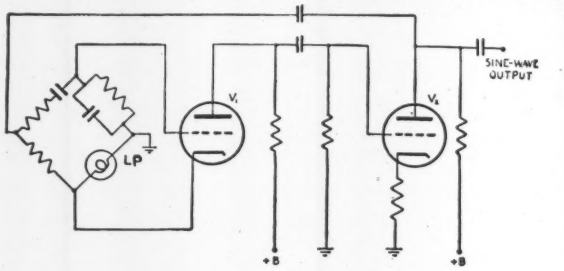


Fig. 10-14. Wien-bridge oscillator.

Note that a signal is fed both to the grid and cathode of the first tube. The grid signal is regenerative; the cathode signal is degenerative. The one frequency at which the former exceeds the latter becomes the resonant frequency. The lamp in the cathode circuit of tube V_1 stabilizes the amplitude of oscillation because its resistance increases if plate current increases, thus reducing the amplitude.

The Wien-bridge oscillator is used commonly in audio test-signal generators. It operates over a wide range of frequencies, it has excellent stability, and the output amplitude is constant over a wide range of frequencies.

Relaxation Oscillators

Relaxation oscillators use the charging and discharging of capacitors to produce trigger action and sawtooth waveforms.

Neon Sawtooth Generator

The simplest sawtooth generator is the neon relaxation oscillator shown in Fig. 10-15. A high positive potential is applied at B+. The potential charges capacitor *C* through resistor *R* at a rate determined by the *RC* time-constant. When the voltage across *C* exceeds the firing potential of the neon glow tube, the tube ionizes and the capacitor discharges rapidly through the tube. The tube acts like a switch which is open when it is not ionized and closed when it is ionized.

When the tube fires, the capacitor discharges and the voltage falls rapidly until it reaches the deionizing poten-

Continued on page 788

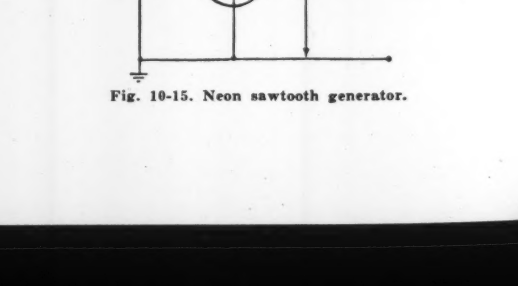


Fig. 10-15. Neon sawtooth generator.

INSTRUMENT SOCIETY of AMERICA Journal

National Office: 1319 Allegheny Avenue, Pittsburgh 33, Pennsylvania

Vol. 8 June 1952 No. 6

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THE MANAGER'S PAGE

Percy V. Jones, Jr.

NOW is the time for all Instrument Men to make their plans to attend the Seventh National Instrument Conference and Exhibit to be held in Cleveland Municipal Auditorium, September 10-14, 1952. September may seem to be a long way off, but all signs point to this being the biggest and best ISA Conference and Exhibit to date and unless you act now you may find it difficult, if not impossible, to obtain hotel accommodations.

At the latest Executive Board Meeting, First Vice-President Wildhack reported on the formation of the new technical committees authorized under the new Society By-Laws. His report included the following information regarding the expected participation of these committees in the Cleveland Conference:

Committee on Medical Instrumentation
Chairman—Dr. H. J. Morowitz—1 to 2 sessions

Committee on Radiation Instrumentation
Chairman—R. W. Johnston—1 session

Committee on Geophysical Instrumentation
Chairman—Dr. D. S. Muzzey—1 session

Committee on Instrumentation for Testing
Chairman—D. C. Little—2 sessions

Committee on Aeronautic Instrumentation
Chairman—R. Tozier—1 session

This information is brought to your attention to emphasize the expanding activities of ISA and to show that it is becoming increasingly more worthwhile to be a member of the Society and to attend its annual function.

This same meeting also heard from Dr. Axel H. Peterson, Chairman of the Committee on Analysis Instrumentation who reported that his plans are well underway for a Clinic on Analysis Instrumentation to be held during the week of and concurrently with the Instrument Conference and Exhibit. Nine Companies are to participate, each Company to give six lectures of three hours duration each. These sessions will take place all day Tuesday, Wednesday, and Thursday at the Cleveland Auditorium. The Clinic, which is an entirely new offering is expected to add greatly to the educational value of the Annual ISA Instrument Conference. (Further details appear elsewhere in this issue.)

The new technical sessions and the new Clinic are expected to broaden the appeal of the Conference with a resultant greater over-all attendance.

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Radiation Instrumentation—Richard W. Johnston
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Recommended Practices—A. V. Novak

**Chairman not assigned*

ISA Emblem Jewelry

Lapel buttons and tie holders bearing the ISA emblem may be purchased by Society Members from the National Office, 1319 Allegheny Avenue, Pittsburgh 33, Pennsylvania.

The attractive gold lapel buttons designed in the shape of the official ISA emblem are inlaid with white enamel and are approximately one-half inch high. Gold filled buttons are priced at $1.50 each and gold plated buttons $5.00.

The tie-clasp and chain, from which is suspended the identical emblem in the form of a key, is gold-filled and priced at $5.00.

The above quoted prices will apply only until the present stock is exhausted.

Committee Selects Nominees for 1953 Officers

G. F. AKINS

Chairman Gerald F. Akins has presented to Dr. A. O. Beckman, ISA President, the report of the Nominating Committee which met on April 25, 1952 at the Hotel Sheraton, Chicago to nominate officers for 1953.

The Committee Members or duly qualified alternates present and areas represented were as follows:

Members present and areas represented:
G. F. Akins—Chairman
D. J. Pompeo—(California, No. California, China Lake, Richland)
J. L. Cottrell—(Denver, St. Louis, Albuquerque, Kansas City, Tulsa, No. Texas, Panhandle)
R. H. Olson—(Central New York, Rochester, Niagara Frontier)
E. I. Thomas—(Charleston, Pittsburgh, Cumberland)
R. R. Proctor—Alternate Council Delegate (Chicago), appointed by Chicago Section to represent J. H. Cuthbert who was unable to attend due to serious illness. (Chicago, No. Indiana, Central Illinois, Twin Cities)
C. M. Bosworth—(Louisville, Cincinnati, Central Indiana)
Ralph Manning—Council Delegate (New York) appointed by W. A. Crawford to represent his area (Washington, Baltimore, Wilmington, Philadelphia, New Jersey, New York)
William Ladniak—(Atlanta, Tennessee, Oak Ridge, Carolina-Piedmont)
R. E. O'Neill—Council Delegate (Houston) appointed by Houston Section to represent J. H. Martin who was unable to attend. (Gulf Coast, Baton Rouge, Houston, So. Texas)
Edward C. Baran—(Cleveland, Akron, Toledo, Presque Isle, Columbus)

Members absent:
James A. Ford and alternate member, George Gardner (Boston, Eastern New York)
John MacPherson and alternate member, Jim Gambrill (Detroit, Wayne County, South Michigan)
F. S. McCarthy (Montreal, Ontario, Sarnia)
James L. Lopez (Aruba)

Members absent but represented by appointees:
Ray Hopper and alternate member J. H. Cuthbert were represented by R. R. Proctor.
W. A. Crawford and alternate member Frank Gregloit were represented by Ralph Manning.
J. R. Martin was represented by R. E. O'Neill.

This meeting, which was the culmination of four months of preliminary work by this Committee, was held in two sessions. The morning meeting was an open session for the purpose of discussing the entire list of suggested candidates. All Candidates Qualification forms received by the Committee were read and discussed at this time. Past President J. B. McMahon and Vice President D. M. Boyd, Jr. were present at this session by invitation.

After recessing for luncheon the meeting reconvened with only Committee Members present. After a detailed discussion of each candidate the Committee voted by secret ballot to select the following slate of new ISA officers for 1953:

For President—Porter Hart, Houston Section

For Vice President—Warren H. Brand, Oak Ridge Section

For Vice President—J. M. Ribble, Panhandle Section

For Treasurer—J. T. Vollbrecht, New York Section

For Secretary (One year term)—W. A. Wildhack, Washington Section

Societies Council Formed

The Albuquerque Section reports that due to the untiring efforts of the Section President, Mr. M. T. Muzzey, an Engineering Societies Council comprised of all the local engineering society sections has been formed. This joint council will function to co-ordinate activities to do the most people the most good. Mr. Muzzey has been named Vice-president of this new organization.

Dr. Axel H. Peterson Announces New Clinic

Dr. Axel H. Peterson, Chairman of the Analysis Instrumentation Committee of the ISA, advises that plans are now completed for the new Clinic on Analysis Instrumentation to be held in conjunction with the Seventh National Instrument Conference at Cleveland, Ohio, September 8-12, 1952.

The Clinic, which will consist of a lecture and demonstration course on complex analytical instruments, will appeal particularly to technicians, chemists, physicists, and engineers. Electronic, optical, and mechanical design features will be covered as well as details of application.

The participating companies and the instruments to be demonstrated are:

BAIRD ASSOCIATES—plant stream analyzer, infrared absorption type

BECKMAN INSTRUMENTS, INC.—flame spectrophotometer

CONSOLIDATED ENGINEERING COMPANY—mass spectrometer leak detector

GENERAL ELECTRIC COMPANY—radioactivity instrumentation

GOW-MAC INSTRUMENT COMPANY—thermal-conductivity gas analysis

MINE SAFETY APPLIANCES COMPANY—combustible gas, oxygen, and Luft-type infrared analyzers

NORTH AMERICAN PHILIPS COMPANY, INC.—x-ray spectrometer and x-ray fluorescence analysis unit

PERKIN-ELMER CORPORATION—double-beam infrared spectrometer

PROCESS & INSTRUMENTS—light scattering apparatus, differential refractometer, recording spectrophotometer (Visible and U.V.) and high vacuum manifold.

In order to limit the size of the groups attending the lectures, admission will be only by previous registration. There will be nine small groups and each of the nine companies will give its lecture and demonstration six times. Thus, each registrant will be able to attend six different lectures and demonstrations. The particular lectures each group hears will vary and at the time of registration each person will select the group best suited to his interest. The program and registration forms may be obtained by writing to Dr. Axel H. Peterson, Mellon Institute, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

Maintenance Clinic Program Announced

Milton M. McMillen, Chairman of the Maintenance Clinic Subcommittee, announces that the Fourth Preconference Instrument Maintenance Clinic will take place at Case Institute in Cleveland, September 5 to 7th, the three days prior to the opening of the Seventh National Instrument Conference and Exhibit.

Excellent Dormitory, cafeteria, and classroom facilities will be available on the campus for those attending. Dormitory rates are $3.00 per night for Single rooms and $2.00 each for Double rooms. Accommodations will be available for about 200 in the dormitories and it will be necessary to limit the number of single rooms to provide facilities for all. Food service will be available in Tomlinson Hall, next door to the Dormitory, and charges will be as reasonable as possible. It is anticipated that meals can be had for about $4.00 per day.

The Clinic Program is as follows:

1. Thermal elements
2. Electrical Measuring Circuits
3. Pressure Elements and Primary Flow Elements
4. Electrical Deflection Indicators
5. Total Quantity Meters
6. Electronics Positioning Devices
7. Pneumatic Positioning Devices
8. Final Control Elements

In addition to the above session, the ISA movie on Automatic Control will be shown at regular intervals. There will be one general session on the Principles of Instrumentation and Automatic Control. The speaker for this General Session will be D. P. Eckman. Classes each day at 9:30 A.M. until 5:15 P.M. Enough instructors are being provided to take care of about 400 students and every effort is being made to keep classes as small as possible within the limit of available facilities.

The Committee has decided to conduct this Clinic with the view toward providing the individuals with the general basic theory of each of the instruments, using several brands of each type for demonstration purposes and supplemented by slides. This approach, with the competent instructors who have been obtained, is expected to result in the most profitable Maintenance Clinic presented to date.

W. F. Sprengnether, Jr.

The National Office has recently heard of the death last fall of W. F. Sprengnether, Jr. Mr. Sprengnether had been a Member of the St. Louis Section since December, 1947.

Paul L. Williamson

The Niagara Frontier Section announces with regret the recent death of one of its members, Paul L. Williamson. Mr. Williamson joined the Niagara Frontier Section January, 1950.

William B. Parsons, Sr.

The National Office has recently learned of the death on May 17, 1951 of William B. Parsons, Sr. Mr. Parsons had been a member of the Boston Section since October 1948.

Hugh D. Stapleton

It is with deep regret that the Eastern New York Section announces the recent death of one of its Student Members, Hugh D. Stapleton. Mr. Stapleton joined the Eastern New York Section in February, 1951.

High Pressure Symposium

One of the highlights of the coming Seventh National Instrument Conference and Exhibit will be the "High Pressure Symposium"—a two-day meeting sponsored by the Industrial Instruments and Regulators Division, ASME.

The Conference and Exhibit, which is expected to attract a record-breaking audience of engineers and scientists, will take place at the Cleveland Auditorium, September 8 to 12, 1952. It is sponsored by the Instrument Society of America with the following cooperating societies: American Institute of Physics; American Institute of Electrical Engineers, Instruments and Measurements Committee; American Society of Mechanical Engineers, Industrial Instruments and Regulators Division.

Papers tentatively scheduled for the "High Pressure Symposium," September 9 and 10, are:

Introduction—Dr. Percy Bridgman, Harvard University.

The Piston Gage for Precise Measurements of High Pressure—Dr. Daniel Johnson, U. S. Bureau of Standards.

Features of a High-pressure Piston Gage—Donald H. Newhall, Harwood Engineering Laboratories.

A High-pressure Wire Gage Using Gold Chrome Wire—Horace Darling, The Foxboro Company.

An Application of High Pressures in Geophysics—Experimental Rock Deformation—Dr. John Handin, Shell Oil Co.

Techniques and Equipment for the Generation of Dynamic High Pressures—E. J. Mickevicz, U. S. Naval Ordnance Laboratory.

A High-speed High-pressure Gage—P. L. Edwards, U. S. Naval Ordnance Laboratory.

Measurement and Control of High Pressures—Speaker to be announced.

Summary Paper—High Pressure Developments at Yale University—Prof. Barnett Dodge, Yale University.

Influence of Residual Stress on Behavior of Thick-wall Closed-end Cylinders—J. H. Fauber and A. R. Furbeck, E. I. duPont de Nemours & Co.

Rupture-disc-design Evaluation and Bursting Tests—G. R. Prescott, E. I. duPont de Nemours & Co.

Round Table Discussion—Safety Precautions in High Pressure Operation.

Studies on Gaskets for High Pressures—Andrew R. Freeman, American Instrument Co.

Design and Application of Controlled-volume Pumps for High Pressures—Speaker to be announced.

Seals for High Pressures—Speaker to be announced.

A Static-dynamic Testing Machine for High Pressures—Speaker to be announced.

Industrial Instrument Training Course Outline

Just off the press is the long-awaited Industrial Instrument Training Course Outline prepared by the Subcommittee on Instrument Mechanic Training under the Chairmanship of George A. Larsen.

This sixty-page report is the first result of a study being conducted by ISA to develop a comprehensive, yet adaptable and easily presented training course on the maintenance level.

Individual topics in each course outline are accompanied by references to selected portions of text books and other source material listed in the last section of the Report as a time saver for both instructor and student.

All full members of the Society will soon receive copies of this Report as one of the benefits of membership. Additional copies of the Industrial Instrument Training Course Outline may be obtained from the Instrument Society of America, National Office, 1319 Allegheny Ave., Pittsburgh 33, Pa. Prices are $.75 to members; $1.50 to others.

Section Secretaries, Meeting Data and Programs

AKRON
Russell F. Marquardt, 1782 Tonawanda Ave., Akron 5, Ohio. Tel: ST-6865
Fourth Tuesday, Meeting 8:15 P.M., U. of Akron, Ayer Hall, Rm. 212-B.

ALBUQUERQUE
W. E. Bostwick, 700 C. North Washington, Albuquerque, N. M.
First Monday, Meeting at 8:00 P.M., Mitchell Hall, Univ. of New Mexico.

ARUBA
J. L. Lopez P. O. Box 203, c/o Lago Oil & Transport Co. Ltd., Aruba, N. W. I. Tel. 2087.
First Tuesday, 7:30 P. M., Engr's Club.

ATLANTA
M. Virgil Davis, 357 Sixth St., N.W. Atlanta, Ga. Tel. EM. 3042
Fourth Friday, Meeting 7:30 P.M., Electric Bldg., Georgia Power Co.

BALTIMORE
G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
G. M. McCarroll, 1813 Edinburgh Ave., Baton Rouge 6, La.
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 7:30 P. M., 99 Club, 99 State St.

CALIFORNIA
Gerald B. Miller, 4622 Halbrent Ave., Sherman Oaks, Calif.
Second Wednesday. Dinner at 6:30 P. M. Meeting at 8:00 P. M.

CAROLINA PIEDMONT
L. Frank Lawrence, Minneapolis-Honeywell Regulator Co., 2400 Wilkinson Blvd.. Charlotte, N. C., Tel: 5-4422
Second Friday, Dinner at 7:30 P.M., Meeting at 8:30 P.M. Cardinal Restaurant, Charlotte, N. C.

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill. Tel: 4-2800
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Norman Krone, 123 N. Grant Ave., Indianapolis, Ind. Tel: IRvington 5337
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
H. G. Murray, 169 Durston Ave., Syracuse 6, N. Y. Tel: 9-9259
Third Monday, Dinner at 6:00 P. M., Meeting at 8:00 P. M.

CENTRAL OHIO VALLEY
J. C. Dilliner, 813 Winton Ave., Belpre, Ohio.

CHARLESTON
D. A. Cunningham, 5140 Washington Ave., S.E., Charleston, W. Va. Tel. 55403
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Airport Terminal Bldg.

CHICAGO
Floyd E. Ertsman, Rm. 1420, Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Hotel Shoreland.

CHINA LAKE
Beuhring W. Pike, 606-A Essex Circle, China Lake, Calif. Tel: 77782
Third Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS, Conference Room.

CINCINNATI
Elmer J. Geiser, 3366 Hubble Rd., Cincinnati 24, Ohio
Second Monday, Dinner at 6:30 P.M., Meeting 8:00 P.M., Engineering Soc. of Cinn.

CLEVELAND
G. D. Carnegie, 3436 Lorain Ave., Cleveland.
Second Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, 2136 E. 19th St.

COLUMBUS
E. M. Chandler, 91 E. Como Ave., Columbus 2, Ohio. Tel: JE 9994.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecelia St., Cumberland, Md. Tel: 583-W
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Alighan Shrine Country Club, Baltimore Pike.

DENVER
G. M. Peters, 3191 W. Denver Place, Denver 11, Colo. Tel: GRand 9073

DETROIT
Frank R. Davis, Edison Institute, Dearborn, Mich. Tel: LO 1-1620 Ext. 5517
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
Robert W. Carter, Sterling-Winthrop Research Institute, Rensselaer, N. Y. Tel. Albany 5-6251 Ext. 262
First Tuesday, Meeting at 8:00 P.M., Siena College, Loudonville, N. Y. Optional Dinner at 6:00 P.M., Circle Inn, Lathams, N. Y.

GULF COAST
Harold Placette, 2440 Neches Ave., Port Arthur, Texas
Last Tuesday, Meeting at 7:30 P. M., Orange County Courthouse, Orange, Texas.

HOUSTON
A. Costa, 714 East 17th St., Houston 8, Texas.
Last Monday, Meeting at 8:00 P.M., University of Houston Library Building.
June 28, Dinner dance, Annual Ladies Night, 7:30 P.M., Houston Country Club

KANSAS CITY
J. C. Brous, 8827 Maiden Lane, Kansas City 5, Mo. Tel: HI 8556
First Tuesday, Meeting at 7:30 P.M., U. of Kansas City, Science Bldg., Rm. 106.

LOUISVILLE
C. M. Bosworth, 5336 Westhall Ave., Louisville, Kentucky. Tel: FR 3494
First Monday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., 712 Dominion Square Bldg., Montreal, Quebec, Canada Tel: UNiversity 6-4725.
Last Monday, 8:00 P.M., Mechanic's Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 520 South 14th St., New Hyde Park, N. Y. Tel: FI-7-0645.
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: WIndsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
Bert L. Anderson, 1951 47th Ave., San Francisco 16, Calif. Tel: SEabright 1-5030
Third Monday, Dinner 6:30 P. M., Meeting 8:00 P.M., Spengers Grotto, 1919-4th St., Berkeley.

NORTHERN INDIANA
J. Baum Beckman, 7145 Wicker Ave., Hammond, Ind. Second Tuesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
George Ritscher, 113 Gorgas Lane, Oak Ridge, Tenn. Tel. 5-1084
First Wednesday, Meeting at 7:30 P.M., Ridge Recreation Hall

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside. Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
Bruno F. Loewen, Philips Chem. Co., Box 1526, Borger, Texas.
Third Tuesday, Meeting at 8:00 P.M.

PERMIAN BASIN
J. B. Jenkins, 509 South Ave. "C," Kermit, Texas. Tel: 3220
Second Tuesday, Meeting at 7:30 P. M., Gulf Oil Corp. Auditorium or Odessa College.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 304, 3147 N. Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellevue-Stratford Hotel.

PITTSBURGH
Dr. A. H. Peterson, Mellon Institute, 5500 Fifth Ave., Pittsburgh 13, Pa.
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash. Tel: 7-8717
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., Foxboro Co., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Hamilton 1468.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Monday, 8:00 P. M., Y.M.—Y.W.C.A.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

SOUTHERN MICHIGAN
Lyle J. Draper, 2233 Oakland Dr., Kalamazoo, Mich.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday After First Monday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
James L. Williams, 2237 Bruce St. Kingsport, Tenn. Tel: 2079-L
Fourth Thursday, Civic Auditorium.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Jerome J. Schwab, Engineering Sales, 516 Guardian Bldg., St. Paul 1, Minn. Tel: GArfield 0601
Fourth Tuesday, Dinner at 6:30 P.M., Meeting 7:30 P.M., Rm. 353, Coffman Memorial Union, U. of Minn.

WASHINGTON
Edward C. Lloyd, 2105 Spencer Road, Silver Spring, Md. Tel: SH. 9340.
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5239.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
E. Avery Taylor, Taylor Instrument Co., Industrial Trust Bldg., Rm. 510, Wilmington, Del. Tel: 9814.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

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Completely Automatic Control System for the Distillation Process

By I. LEFKOWITZ*

AN industrial process' function is the conversion of raw material into a desired intermediate or end product. The rate of production, economy of operation, and quality of the product are determined, to a large extent, by the physical and chemical conditions maintained. Presumably, optimum values for the process variables (temperature, pressure, composition, etc.) have been obtained through laboratory experiments, pilot plant data, and accumulated production "know-how". Instrumentation provides the means for reproducing those optimum conditions which will ensure desired process performance.

Variations in operating conditions affect the rate, efficiency, and quality of production. The relative magnitude of this effect is dependent upon the nature of the process and in turn determines the type and degree of instrumentation required to achieve desired results.

Approach To Control Problem

The extent to which the process is to be instrumented also depends upon the design of the equipment and the rigidity of the product specifications. Much can be done toward simplifying and increasing the effectiveness of the measuring and control system by engineering the instrumentation into the original process design rather than the more conventional approach of instrumenting the finished product.

Thus, the significance of a given measurement, or the stability of a given control is directly responsive to the considerations given in the design of the equipment to such factors as: process response characteristics, capacities, deadtime, extraneous variables, and the locations of the sensing and control elements.

It is worthwhile to note that much can also be done toward simplifying and reducing the capital outlay for processing equipment through an instrumentation progressively oriented. For example, an adequate control system which can compensate for process variations, reduces the need for such averaging techniques as surge tanks, stabilizing sections, and capacity chambers. The savings in equipment, plant space, and inventory of material in process may far outweigh the cost of the additional instruments.

As another example, it is not uncommon for equipment to be designed with a large factor of safety to take care of normal variations in operating conditions. However, as the process control is improved through additional instrumentation, the need for this overdesign is minimized.

As mentioned above, a relationship exists between the degree of control and the quality of the product. Any random variations in the process operating conditions will affect to some extent the composition, purity, and quantity of product produced. Obviously, if such a variation exists, either the product specifications must fit an average product quality or a large percentage rejection must be accepted. By reducing the amplitude of such variations through adequate control methods, product quality standards can be raised.

The Seagram organization has responded to these ideas by encouraging the design and development of completely automatic control systems for the various distillery processes. Perhaps the best example of the progress in this direction is the instrumentation developed for the distillation column.

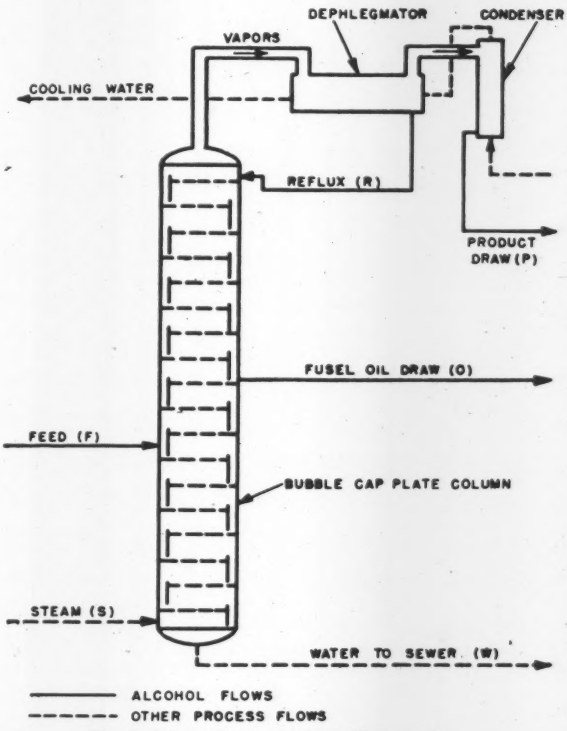


Fig. 1. Schematic of typical distillation column.

Outline of Distillation Control Problem

The distillation unit for the production of beverage spirits (highly refined alcohol) consists of a number of interconnected fractionating columns each of which performs a specific function in the purification and concentration of the product. Control of this process is rather critical because of the following factors:

(1) The columns are closely interrelated through material flows from one to the other, common utilities, etc. Process variations in any one column or utility supply fluctuations are generally reflected throughout the system.

(2) Alcohol losses must be kept to an absolute minimum because of the high economic value of the product and government restrictions placed on its processing.

(3) Very small traces of various fermentation by-products have a pronounced effect on the quality of the product. These are organic compounds generally classified as aldehydes, esters, fusel oil, etc. The efficiency of removal of these other constituents or *congeners*, as they are called, is directly related to the degree to which optimum equilibrium conditions can be maintained.

(4) The control characteristics of the distillation column are very poor because of excessive dead time and process capacity.

A schematic representation of a typical column is shown in Fig. 1. Some of the flow streams and other details have been deleted in order to simplify the following presentation. The feed, consisting of an alcohol-water mixture

*Joseph E. Seagram & Sons, Inc., Louisville, Ky.

Presented at the Sixth Annual Conference of the Instrument Society of America, at Houston, Texas, Sept. 10-14, 1951.

containing small amounts of fusel oil*, is introduced into the column at some intermediate plate. The alcohol rises in the column and is drawn off the condenser as product.

The water tends toward the bottom of the column where it is exhausted to the sewer. The characteristics of the fusel oil are such as to make it concentrate in a relatively narrow band at about the middle of the column. A stream, referred to as the *fusel oil draw*, is taken off the column at the plate of highest fusel oil concentration. Vapors are produced by steam entering the base of the column and condensed by cooling water in the dephlegmator and condenser.

Necessary Column Conditions

In order for the column to function properly and remain in equilibrium, the following conditions must be satisfied:

Material Balance

(a) The quantity of alcohol entering the feed must equal the total leaving in the product and impurity draw streams. Any discrepancy between input and output will result in either a build-up or depletion of alcohol in the column, leading respectively to alcohol losses out the bottom or lowering of the product concentration.

(b) Congeners must be withdrawn from the colunm at the same rate they enter in the feed. Too low a draw rate causes an accumulation of fusel oil in the column which would eventually find its way into the product. Too high a draw rate adds to the load on the system with a consequent lowering of the over-all efficiency.

Energy Balance

(a) Energy is supplied to the column in the form of steam. Too little steam will not do the job; too much is poor economy.

(b) Energy is absorbed by the condenser cooling water. Just enough heat should be removed from the vapors to condense them at their saturation temperature. Insufficient cooling is wasteful of water and results in the reflux being cooled to some variable temperature which may adversely affect the column equilibrium.

Alcohol Concentration Control

The location of the fusel oil concentration band is a function of the alcohol concentration gradient through the column. In order to maintain the maximum fusel oil concentration at the fusel oil draw plate, the alcohol concentration on this plate must be kept within rather narrow limits.

*In this and the following discussions, only the removal of the fusel oil constituent is considered. The same principles apply, however, to the processing of each of the other fermentation by-products which are taken out of the product in the distillation process.

Limitations of Older Controls

The original control on this column was limited essentially to the following:

(1) Steam input controlled by the column base pressure.

(2) The product flow controlled by the temperature on the fusel oil draw plate. This mid-column temperature control served the double purpose of maintaining the material balance and controlling the concentration on the fusel oil draw plate at the optimum equilibrium value.

(3) Condenser cooling water controlled by the temperature in the vapor side of the condenser.

(4) Hand control of all other flows.

Some of the more obvious limitations to this system of control are:

(1) Base pressure is not a valid criterion of the energy supplied to the column since it is affected by many other column variables (base level, liquid throughput, condenser temperature, condition of the plates, etc.) Furthermore, there is no compensation for the actual energy needs of the column. To be on the safe side, the column would normally be operated with enough excess steam to take care of all anticipated variations.

(2) The plate temperature is a valid measurement of the alcohol concentration provided that both the static pressure and the fusel oil concentration on the plate remain constant. Unfortunately, neither condition can be relied upon in average column operations.

(3) The sensitivity of the temperature element to change in alcohol concentration is comparatively low. Any attempt to narrow the range of the instrument to make it more sensitive to concentration changes would at the same time increase the static pressure error.

New Control Approach

There are three essential elements to the revised instrumentation of this column. These include:

(1) Flow ratio controls (Material Balance)

(2) Reflux-steam control (Energy Balance)

(3) Concentration controller (End-Point Control)

Material balance is maintained by the flow ratio control of all the draw streams to the feed flow (see Fig. 1). Expressed algebraically:

$$Fx_f = Px_p + Ox_o \qquad (1)$$

$$P = K_pF \qquad O = K_oF \qquad (2)$$

where F, P, and O refer respectively to the rate of feed, product, and fusel oil flows; x refers to the alcohol concentration of the flow denoted by the subscript, and K is the setting on the flow ratio controller between the feed and the flow denoted by the subscript.

Combining Equations 1 and 2, the feed term drops out:

$$x_f = K_px_p + K_ox_o \qquad (3)$$

With the automatic controls functioning properly, the composition of the product and fusel oil draw streams should be fairly constant. Similarly the feed stream should not vary appreciably in concentration since it comes off a column which is also controlled. Thus, definite values for the flow ratios K_p and K_o can be chosen to satisfy the conditions of Equation 3 for all rates of feed flow.

Since the feed flow is a measure of the load on the column, it follows that the flow ratio control system maintains the material balance over varying column load conditions. The compensation for a load change is extremely rapid because of the high response speeds of the flow controls.

Ratio Control of Reflux to Feed

A change in load on the column means also a change in the amount of work to be done by the column, hence should correspond to a proportionate change in energy supply. This could be done by ratio-controlling the steam to the feed. However, the control system goes one step further. The reflux flow is ratio-controlled to the feed flow, the steam flow index being set by the reflux flow controller. Advantages of this modification are:

(a) Variations in steam pressure and quality have no effect on the accuracy of the energy-load relationship.

(b) Partial compensation is made for variations in column heat losses.

The equation for the reflux flow is:

$$R = K_rF \qquad (4)$$

where R is the rate of reflux returned to the column and K_r is the ratio set between the feed and reflux flows.

Theoretical plate to plate concentrations are determined by both the alcohol-water equilibria and the operating line equation. Making certain simplifications, the operating line above the feed plate is expressed by Equation (5):

$$Y = \frac{R}{R+P}X + \frac{Px_p}{R+P} \qquad (5)$$

where X is the alcohol concentration in the liquid of any plate above the feed, with Y as the concentration of the vapors from the plate below.

With ratio controls (combining Equations 2, 4, and 5) this reduces to:

$$Y = \frac{K_r}{K_r+K_p}X + \frac{K_px_p}{K_r+K_p} \qquad (6)$$

or $$Y = aX + b \qquad (7)$$

This is the equation of a straight line and expresses the linear relationship between the vapors composition of one plate and the liquid composition of the plate above. A similar equation can be derived for the section of column below the feed entry plate.

Combining these relationships with alcohol-water equilibria, we find that, theoretically at least, the instrumentation up to this point should tend to maintain a constant concentration gradient over the column. In other words, the concentration at different points in the column should remain constant independent of the rate of feed or load to the column.

The foregoing conclusions are based on several assumptions and simplifications which were made in the theoretical analysis. There are some limitations, therefore, to the control system as outlined thus far, namely:

(1) Constant feed and drawoff compositions were assumed. Actually, slight variations in the alcohol concentration of these flow streams must be expected. Unfortunately, because of the continuous nature of the process, any deviation between input and output is cumulative and will lead to a change in column equilibrium.

(2) By the same token, slight discrepencies in the measurement of the input and output flows would be auditive and, over a period of time, would upset the column equilibrium. Since commercial flow meters may be inaccurate up to several per cent, this point is particularly important.

(3) The equations describing plate to plate compositions are only approximate for the practical column. Variations in plate efficiency, concentration gradient across the plate, ambient heat losses, latent heats, etc. all tend to upset the theoretical relationships.

Use of End-Point Controller

An end-point controller is employed to detect and compensate for deviations from column equilibrium. An instrument measuring alcohol concentration is installed on the fusel oil draw plate located in the middle of the column. Any buildup or depletion of alcohol in the column causes a change in concentration on the plate and is detected by the concentration instrument. Such a change indicates a discrepancy in the ratio setting between feed and product flow.

This ratio is corrected by means of a pneumatically variable ratio controller setting the product flow. The product is still ratioed to the feed; however, the ratio is automatically determined by the output of the concentration controller. Thus, a change in load on the column is immediately compensated by a proportionate change in product draw. Any additional correction that may be necessary is then applied by the concentration controller.

It might be argued at this point that the flow-ratio control system performs no useful function since the concentration controller is still required to correct for its errors and inadequacies. Essentially, the purpose of the elaborate instrumentation outlined above is to compensate for the extremely poor control characteristics inherent in the distillation process.

The distillation column is made up of a large number of fractionating plates each containing an appreciable quantity of liquid. This liquid zigzags its way down the column plate by plate, countercurrent to the vapors moving upward. The equilibrium on each plate is determined by the relative rates and concentrations of vapor rising from the plate below and liquid from the plate above.

Any change in column operating conditions starts a stepwise plate to plate reaction which gradually brings the column to a new state of equilibrium. This process can be extremely slow in terms of instrument control. Considering the mid-column concentration instrument as the final control element for the column, the following factors govern its effectiveness:

(1) Column capacity lag.

(2) Plate to plate liquid and vapor flow rates.

(3) Sensitivity of the concentration measuring instrument.

(4) Speed of response of the measuring and control system.

(5) Location of the sensing element.

Effects of Capacity and Flow Rates

The capacity of the column determines the quantity of material which must change concentration in response to a change in operating conditions. Since the concentration change must exceed the sensitivity threshold of the concentration instrument before it can be detected, the dead time involved will be directly proportional to this capacity. Unfortunately this factor is a characteristic of the equipment and little at this stage can be done to improve it.

The rate of liquid and vapor flows through the column determines both the speed with which each new plate equilibrium is reached and the rate at which a change is communicated throughout the column. As an example, the concentration controller exercises corrective actions on the column by adjusting the product draw rate. The top plate is the first to respond to this change. Then, after the top plate overflow has altered composition sufficiently, the next plate below begins to feel the effects and so on down the column.

By the time the concentration controller senses the effect of its control action, an excessive period of time has elapsed. The corrective action may easily have been too little or too much, in either case the column remains out of equilibrium over extended periods of time. Here again, once the column is designed and installed, little improvement can be expected in this direction.

Importance of Control Sensitivity

The sensitivity of the concentration instrument is important because, to a limited extent, increased sensitivity reduces the effects of process capacity lag. As the instrument is made more sensitive, it will detect a change in column equilibrium much sooner and thereby instigate the required control action much more rapidly. For example, assuming the change in concentration to be a function of time, an instrument sensitive to a one per cent change should react in half the time it takes one sensitive to only a two per cent change.

In general, the amplitude and duration of the column deviation from equilibrium is inversely related to the sensitivity of the concentration controller. It is advantageous, therefore, to make this instrument as sensitive as possible. However, there are practical limitations.

In the application of the temperature instrument as a method of concentration control, the limiting sensitivity is determined by the effect of static pressure variations on the temperature concentration relationship. As the instrument is made more sensitive, the errors introduced by normal column pressure variations become very significant.

The answer to this limitation is a concentration measuring instrument which is relatively unaffected by static pressure variations. One such instrument is based upon a comparison of the vapor pressure of the liquid in the still with the vapor pressure of a standard solution of known composition maintained at the still temperature. Within the useful range of the instrument, the deviation in vapor pressure is proportional to the difference in concentration between the still liquid and the standard.

Concentration Controller Developed

The concentration instrument developed for this purpose is illustrated schematically in Fig. 2. A bulb containing the standard solution is located on the plate whose concentration is to be measured. The bulb is connected to one side of a diaphragm, the other side being directly exposed to the static pressure above the plate. Since the liquid on the plate is boiling, this static pressure is equivalent to the vapor pressure of the liquid.

The difference in pressure is balanced by a pneumatic pressure acting on the small feed-back diaphragm. Unbalance is detected by the flapper and nozzle system and corrected by action of the pilot. The feed-back pressure is proportional to the difference in vapor pressure and is, therefore, related to the concentration of the liquid on the plate. It forms the actuating pressure for the concentration recorder and controller.

The sensitivity of this concentration controller has been increased many times over that of the temperature instrument performing the same function. The factors limiting the sensitivity in this case are: (a) the effects of temperature and pressure transients and (b) the concentration gradient across the plate due to the cross-plate liquid flow.

Although the lags in the concentration measurement and controller action are small in comparison with that of the process, this is a case where "every little bit counts". If several minutes can be shaved off the time required for an equilibrium displacement to be detected and corrected, then that represents a corresponding

reduction in the deviation of the column from optimum conditions.

Accordingly, the concentration controller has been designed for a maximum response speed. The instrument is of the force balance type employing a pilot of special null balance design which allows almost no displacement. Since the capillary flow is negligible and the bulb can have a large surface to volume ratio, the response to a change in concentration is extremely rapid.

Location of Sensing Element

The location of the bulb or sensing element of the concentration instrument has a great effect on the controllability of the process. The plate to plate change in concentration in an alcohol distillation column is not uniform but varies from almost no gradient over the top and bottom sections, to a very sharp gradient near the middle of the column. The best location of the sensing element is in this region of rapidly changing concentration because it is here that the system is most sensitive to a shift in equilibrium. By this means, the effective sensitivity of the concentration instrument is increased.

Fortunately, this region of maximum sensitivity coincides with the fusel oil band location. The fusel oil draw plate is therefore the optimum location for the sensing element of the concentration controller. Increasing the sensitivity and speed of response of the concentration controller, and correctly locating the sensing element have improved the control of the distillation column considerably. However, the limitations imposed by the equipment design still dominate the situation. At its best, the time lag beween control action and measured response remains excessive for stable column operation.

This difficulty has been resolved to a large extent by the addition of the flow-ratio control system. This system essentially anticipates a change in column equilibrium and applies immediate corrective action. Thus, the major portion of the control action is effected by the rapidly responding flow-ratio controls, leaving to the concentration controller only a relatively small corrective action. As a result, the deviation of the column from equilibrium is kept to a minimum.

Advantages of Ratio Control

There are some additional advantages of the flow-ratio control system.

(1) The relationship between input and output can be calculated and the flow ratios set to give the correct control responses over the range of column operation.

(2) The flow ratio controls maintain energy balance and reflux ratios consistent with the theoretical load demand on the column. Concentration control alone merely compensates for material balance discrepancies and does not consider other column variations.

(3) The rate of fusel oil draw is varied with the load on the column, assuming the rate of fusel oil input to be proportional to the feed flow. To be absolutely correct, a fusel oil concentration controller should be included in the instrumentation to automatically vary the fusel oil draw ratio to maintain optimum column (or product) fusel oil concentration. However, since the fusel oil forms a very small percentage of the total input, normal variations in its concentration are insignificant in terms of the overall control problem. An average ratio setting of the fusel oil draw is therefore adequate.

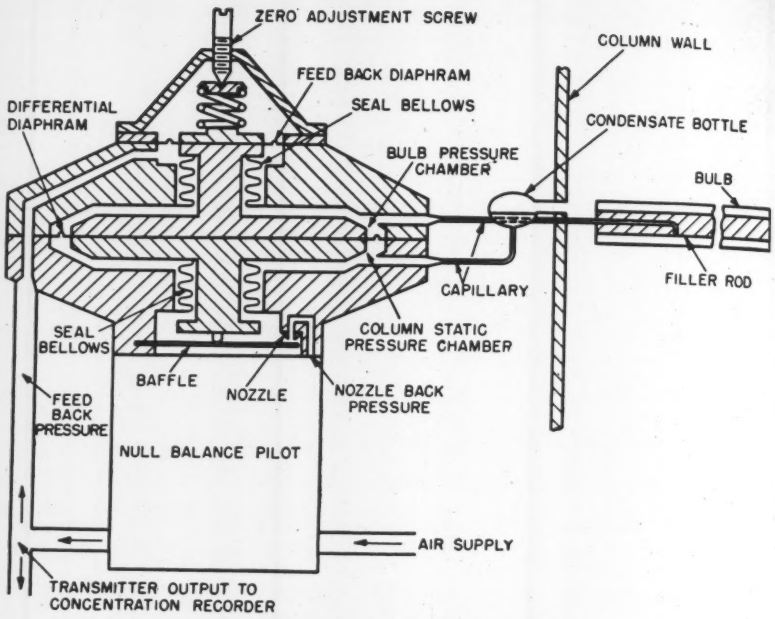


Fig. 2. Schematic of concentration controller.

Use of Cascade Control

Cascaded control principles are employed in another way to offset unfavorable process control characteristics. Where there is an appreciable time lag between measurement and control response, as for example in the application of temperature or concentration control, intermediate control actions are used. In general, the slow responding primary controller sets the index of a flow controller which in turn actuates the automatic valve to give the desired control action. By this means, the final flow rate can be accurately related to the primary variable irrespective of valve characteristics.

Secondly, the flow is maintained constant for a given primary controller output independent of such variations which would tend to affect the flow through the valve. There are several places in the distillation control system where this type of cascading is used to advantage. These include:

1. Condenser temperature controller setting the index of the water flow controller.

2. Concentration controller varying the product draw through the product flow controller.

3. Reflux controlling the steam flow controller.

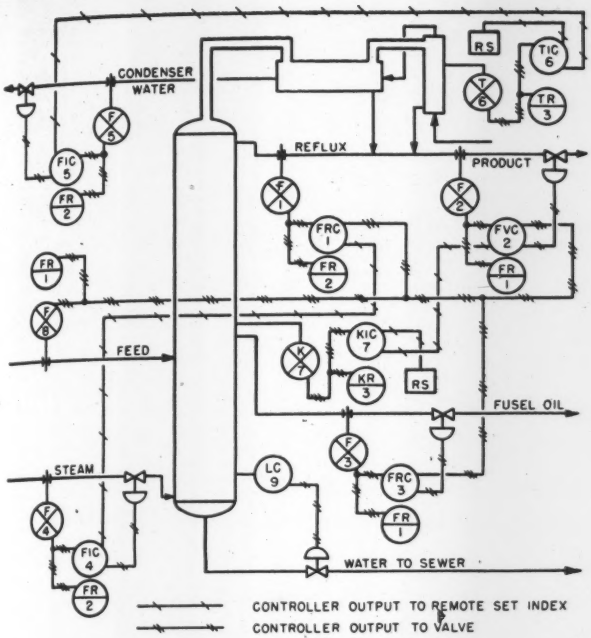
A schematic representation of the final control system for the simplified column of Fig. 1 is shown in Fig. 3. This system has been put into operation on several distillation columns with a high degree of success. The step conversion of the first columns made it possible to observe the improvement in column control with each improvement in the instrumentation.

This improvement could be expressed in terms of closer mid-column concentration control, faster recovery of column equilibrium following an upset, greater stability of column operation, and most important, a more uniform production at the desired quality level. Perhaps the easiest factor to illustrate is the improvement in the mid-column concentration control of one of the columns. Representative charts at the various stages of development of the control system are shown in Fig. 4.

Discussion of Chart Records

The original instrumentation of the column was as outlined previously in this paper. The product draw was usually manually regulated because the mid-temperature control was too unstable and, in general, gave poorer results. The concentration record under these conditions is shown as *A* in Fig. 4.

Chart *B* of Fig. 4 shows typical results obtained with automatic control of the product draw by means of the concentration controller. Two improvements were noted; first, automatic control of the column was now fairly dependable and stable and secondly, the concentration variation was decreased considerably. The simultaneous mid-column temperature record is reproduced in *C* of Fig. 4 to illus-



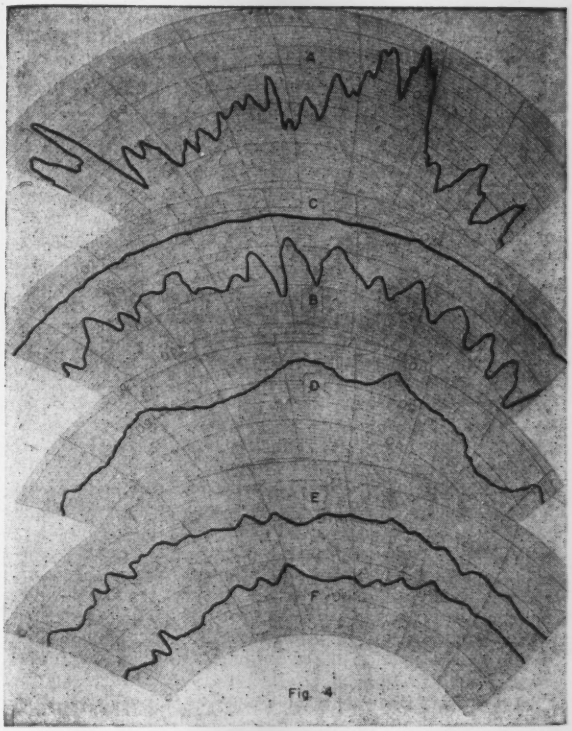


Fig. 3. (left). Final control system Fig. 4 (above). Concentration records.

trate its comparative insensitivity to the observed changes in concentration.

Chart *D* of Fig. 4 indicates some of the improvement obtained through the addition of flow ratio controls. More significant, but not quite as apparent, was the improved response to wide ranges of column operation.

The present stage of development of the controls on this column is typified by the concentration record *E* in Fig. 4. The original concentration controller was replaced by the null-balance instrument illustrated in Fig. 2, coupled with one of the new force-balance type controllers. Again, significant improvement in column stability and constancy of operating conditions was the result.

The product draw flow corresponding to the concentration record *E* is given in *F* of Fig. 4 to illustrate normal column load variations. In this case, the change in alcohol throughput was about 15 per cent over a period of hours. The instrumentation is called upon to handle still greater and more rapid load changes during the startup and shutdown operations which must occur weekly, during upsets which periodically result from equipment and utilities failures, and finally during normal changes in the distillation rate as determined by the production schedule.

Acknowledgement

The cascaded control system as outlined in this paper was developed under the direction and personal stimulus of Mr. E. H. C. Brown of Joseph E. Seagram & Sons, Inc. The author wishes to acknowledge the guidance and assistance rendered by Mr. Brown in the preparation of this paper.

Practical Application of Servomechanism Techniques to a Process Control Problem

By S. P. HIGGINS, JR.* and G. W. McKNIGHT**

ABSTRACT. A typical problem in this field—namely, a flow system—is analyzed by servo techniques. Predictions of system behavior by this method are then correlated with the results obtained from the actual system tests.

PROCESS control, since its inception, has been aimed toward most efficient use of process facilities to produce a uniform product of high quality. As processes and their associated control problems become more complex, the need becomes apparent for systematic analysis, with the problem expressed in terms of numbers, to supplement practical experience. The so-called "servo techniques" seem to offer a powerful tool for expressing process control problems in terms of numbers.

This paper attempts to show the usefulness of the servo methods for predicting system behavior on an actual process. Previous papers have presented data derived from these methods on hypothetical processes and showed predicted results, but little data appears to be available in the literature showing *test* results on a physical system for comparative purposes. The paper attempts to show that even simple servo methods provide useful information for process instrumentation.

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Origin of Servo Techniques

The search for a mathematical approach to process design and control application is not a new one. In the early stages, attempts were made to write differential equations for process and instruments to effectively define their operation. The complexity of equations and difficulties experienced in assigning numbers to the coefficients were sufficient to make the methods impractical. Methods based on empirical formulas, such as the transient or step change method[1] were more practical and did receive some acceptance, although the size of the disturbances to the process required and the degree of

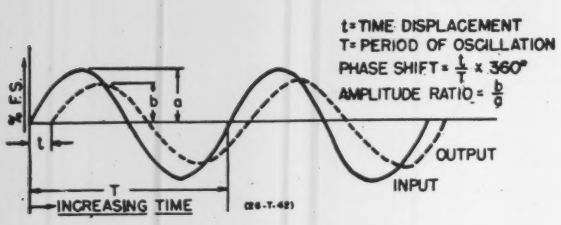

Fig. 1. Output response of a passive network to a sinusoidal input disturbance.

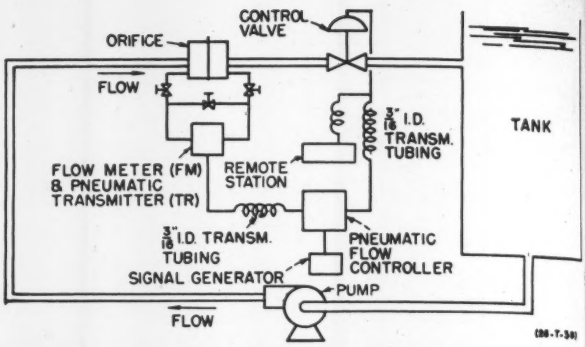

Fig. 2. Flow loop.

accuracy attained led many to use intuition, good judgement and experience rather than any formalized approach to solve the problems.

During the last war, great progress was made in predicting the performance of combinations of devices for anti-aircraft artillery use. The methods were taken from many fields including feed-back amplifier and electrical filter circuit design. Collectively these have become known as the *servomechanism techniques*. Since the factors involved in effectively laying a gun are in many ways very similar to those of process control, it is only logical that the servo theory should be applied to process analysis.

As occurs in the positional servo devices for anti-aircraft artillery, limitations of many physical components used in the process industries—such as pumps, heat exchangers, controllers, valves, measuring and transmitting devices—have combined effects on the quality and quantity of the end product. Naturally, for most efficient operation of a plant, each such component should be correctly specified for the job. Thus, the process and its instrumentation must be considered jointly during the plant design stages rather than separately as in the old practice of designing the process and later adding the instruments. Naturally, compromises may have to be made since important factors other than the ultimate in performance must also be considered.

The experience of G. S. Brown and D. P. Campbell with the application of servo techniques to system design prompted them to propose the need for men trained in these many phases of process control and instrumentation to be called *System Engineers*.[2] Before system engineering is feasible, however, methods of analyzing the various components of the system and for predicting their combined behavior must be made available on a practical basis.

As a vehicle for crossing the boundary between the process and instrumentation phases, servo techniques seem to offer many advantages. Most people, however, when confronted with the term *servo techniques*, think, immediately, of involved terminology and mathematicians equipped with computers. Such is not necessarily the case. This can best be proved by examining the techniques themselves.

What Servo Techniques Are

Each component or process to be tested is essentially an energy transferring or modulating device; that is, if a change is made to the input of the device, at some later time there will be a related change in its output. Obviously, the nature of the input signal, the device construction, and especially the relative ability of the device to transfer energy will determine the amount by which the output lags or leads the input as well as the degree of amplification obtained from the device. This energy transferring characteristic is known, in the servo field, as the *transfer function* of the device. (In the case of an energy modulating device, such as a controller, the transfer function is a measure of the regulating ability of the device).

One of the most practical ways of determining the transfer function of a device or process is to observe its response to a sinusoidally varying disturbance. This is commonly known as the *Frequency Response Method*. If the system under test is linear, the output response must also be sinusoidal with time; that is, the frequency of the response sinusoid must be identical with the frequency of the disturbing sinusoid.

It is realized that most systems are not linear. Non-linearities, due to valve characteristics, hysteresis, friction and other losses, exist in all processes. However, if the band of operation is kept within a relatively narrow range, the system will usually be sufficiently linear to permit the successful application of servo methods for predicting system behavior within this range.

Use of Frequency Response Plots

If the sinusoidal disturbance is introduced, as above, the dynamic characteristics of the component under test will determine the ratio of the magnitudes of the output to the input signal and will cause them to be displaced timewise. If the frequency of the disturbing signal is changed, a new magnitude ratio and a different amount of phase shift will occur after the transient has died out. The transfer function and hence the dynamic performance of the unit is determined by measuring the ratio of output amplitude to input amplitude and by measuring the phase shift between the curves over a range of input frequencies. This is shown diagrammatically, in Fig. 1, for one value of input frequency.

If sinusoidal disturbances are introduced into a process or component at different frequencies, (such as by loading a valve in a process) a series of amplitude ratios and phase shift angles will be determined. If plots are made of Amplitude Ratio and Phase Lag against frequency of disturbance, the resultant curves establish the dynamic characteristics for the component or system under test. These plots are known as *Frequency Response Plots*.

Although the frequency response plots themselves give valuable information, as is shown later, some correlation to system performance, such as the response of a system to a change in controller set point, must exist so that the data has practical utility. Various methods are available for making this correlation, one of which is used in the analysis to be described. It is of interest to note that the transfer function plots themselves indicate the method to be chosen as well as the probable accuracy associated with the correlation.

Obviously the above is an oversimplified outline of the techniques, and does not indicate some of the physical difficulties involved. One difficult problem is the design of a signal generator and recorder capable of producing an undistorted sinusoid over a wide range of frequencies, with pneumatic, electrical and motion outputs. This has been accomplished and information concerning it will be published at a future date. Similarly, the necessity for evaluating the frequency data in terms of the previous process and control experience cannot be discounted, and this problem will be discussed later in the paper.

Description of Control Loop Selected

To facilitate testing, it was desired to have available a simple process control system having sufficient physical significance to be associated with actual processes. Experience indicated that a flow control system could be constructed in the laboratory to meet the above requirements. This flow control loop is shown schematically in Fig. 2.

A centrifugal pump is used to pump water around the loop and back into the sump tank. The flow is measured by conventional orifice methods. The length of connecting tubing be-

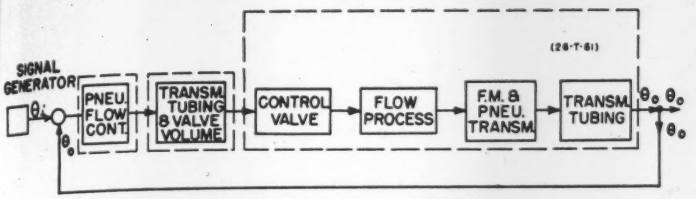

Fig. 3. Block diagram of flow control loop.

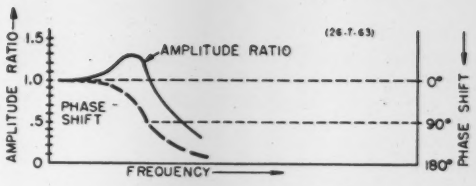

Fig. 4. Response of a simple system.

tween the meter, controller and control valve can be varied along with the appropriate side tubing lengths so as to show the response for a process-mounted controller as well as for a controller mounted in the control house. In addition, flow meters of the mercury and dry type are tested with the controller in the locations mentioned above. The signal generator is the device which loads the system or system components with a sinusoidally varying disturbance.

The various elements of the system of Fig. 2 may be represented as a series of blocks as shown in the block diagram of Fig. 3. The signal generator is an analytical tool only and forms no part of the automatic flow control system. The breaking up of the system into the parts indicated by the blocks is done so that the parts can be isolated as needed for analysis and design. The ultimate objective is to identify or tag each block in such a way that we can determine what the design of each of the blocks should be for optimum performance of the system as a whole. This, in the language of the servomechanism engineer, is a method offering means for analysis of the elements or blocks that exist or synthesis of those yet to be designed.

It may be more convenient, in certain cases, to have the block represent two or more components in the system, such as the valve and process. The individual transfer function for the process could then be obtained if the valve transfer function (i.e., the response in valve position to valve pressure) were known. The dotted blocks of Fig. 3 show one instance where the transfer function across a group of components might be studied, rather than the individual transfer functions of the components themselves.

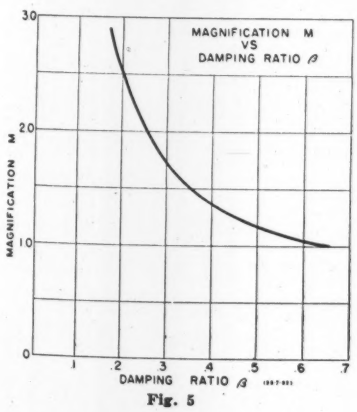

Fig. 5

Application of Method to Ideal System

Before the use of the frequency response method on the flow control loop is described, its application to a hypothetical example will be considered to see what results might be expected. If the system under test acts in certain respects like a simple system, such as the common two capacity process control system, many useful approximations can be made. For example, such a system, if subjected to a sudden set point change, might have a damped oscillatory response, as evidenced by over and underpeaking, with each successive peak smaller in magnitude than the last. An example of this type of recovery is the well known *quarter amplitude recovery curve*. Such a system, if subjected to sinusoidally varying set point changes would have a closed loop frequency response as shown in Fig. 4.

Note the amplitude peak and the rapid change of phase at the resonant frequency. If the frequency response of the system under test resembles the response of the simple system in the region of resonance, some simple methods can be applied to approximate system transient response from the system frequency response. From the relative height of the amplitude peak and the frequency at which it occurs (the resonant frequency), the transient response can be approximated by the use of Figs. 5 and 6.

Fig. 5 shows the damping ratio β as a function of the amplitude ratio (magnification). With the damping ratio established, Fig. 6 shows the transient response in terms of the damping ratio and the natural frequency. As shown in the diagram, the natural frequency is related to the resonant frequency by the equations below.

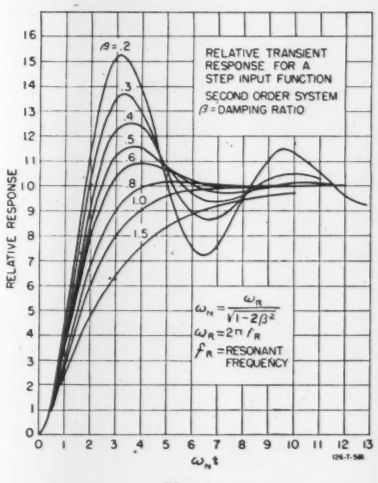

Fig. 6

$$\omega_N = \frac{\omega_R}{\sqrt{1 - 2\beta^2}} \qquad (1)$$

$\omega_R = 2\pi f_R$
ω_N = natural frequency (radians/min)
ω_R = resonant frequency (radians/min)
f_R = resonant frequency (cycles/min)

Thus the height of the resonance peak indicates the degree of damping and the resonant frequency indicates the time for recovery. A high peak, showing a relatively low damping ratio, would indicate that the transient response to a set point change would have large over- and undershoots, as indicated for the smaller values of β on Fig. 6. A system having high resonant frequency would require a shorter time for recovery than one having a low resonant frequency. The abcissa of the curve of Fig. 6 is expressed as $\omega_N t$.

Thus the curve is easily dimensionalized with respect to time by observing the value of $\omega_N t$ for the point in question. Time is given by the expression below:

$$\text{Actual Time} = \frac{\omega_N t \text{ from Fig. 6}}{\omega_N} \qquad (2)$$

The closed-loop frequency response can be measured, or it can be derived from the frequency response of the components used to make up the closed loop. If for example, A, B and C are components for which the transfer functions are known, the over-all open-loop transfer functions can be determined by multiplying the amplitude ratios and adding the phase angles. Thus, the open-loop frequency response for one frequency is shown:

$$M_S = M_A \times M_B \times M_C \qquad (3a)$$
$$P_S = P_A + P_B + P_C \qquad (3b)$$

where M = amplitude ratio
P = phase lag

With the amplitude ratio and the phase lag established for a number of these frequencies, the open-loop transfer function of the system comprised of the components is, in effect, predicted. The conversion from the open-loop frequency response of the system to the closed-loop frequency response is easily accomplished graphically or by charts which will not be discussed here.[3]

Thus, it has been shown that the closed-loop frequency response which is representative of the system transient response can be measured on an existing system or computed from the component responses.

Description of Test Procedure

To test the validity of the assumptions, four different flow control systems as described in Table I were examined using the methods just described.

Thus, the test data will be presented for a typical flow control problem showing the relative effect of controller location as well as a comparison of wet and dry meter operation.

The flow meters were mounted at the orifice using conventional manifolds. The final control element was a standard control valve. No valve positioner was used and the hysteresis curve for the valve is shown in Fig. 7. Transient plots (response to a sudden step change in set point) were obtained using two conventional, two-pen pneumatic receivers with 30-second and 6-minute chart drives.

For simplicity, controller adjustments were made for each system on the basis of transient response to set point changes. No attempt was made to obtain optimum settings for each case so that the systems can not be directly compared from the data. This was done since the purpose of the paper is to show the practical applicability of the approach rather than to provide detailed system information.

Both the set point and the transmitter flow signals were recorded, following a sudden (10 percent of full scale) change in set point pressure. After these transient tests the controller was subjected to a sinusoidally varying set point pressure covering approximately 20 percent double amplitude. The flow signal at the controller was then recorded and plots made to show the amplitude and phase of this signal referred to the set point signal.

This plot established the closed-loop frequency response for the system under test. The correlation of transient response by the graphical methods previously described to the closed loop frequency response was checked at this time.

With the correlation between the over-all system frequency and transient response established, the components contained in the closed loop were individually tested for their response to sinusoidal forcing signals of small amplitude and at the level at which they operated for the closed-loop frequency response tests. The data thus obtained consisted again of amplitude ratio and phase angle between the component output signal and the sinusoidal input

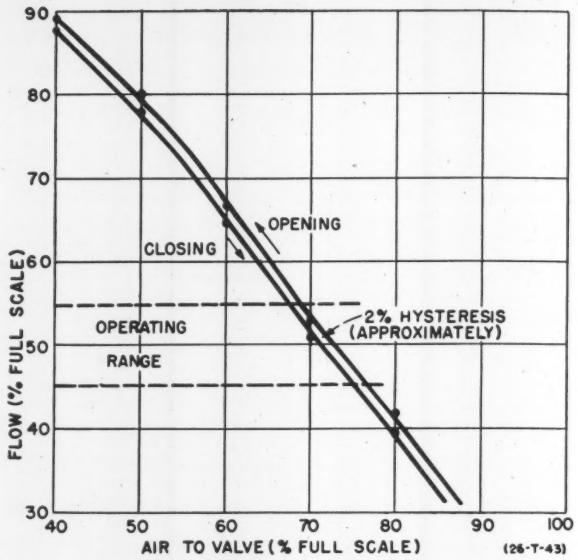

Fig. 7. Control valve characteristics.

TABLE I—FLOW CONTROL SYSTEMS

System	Type of Flow meter	Distance in feet from Transmitter to Controller*	Distance in feet from Transmitter to Remoteset*	Distance in feet from Controller to Valve*	Distance in feet from Controller to Remoteset*
A	Mercury Meter	150	150	150	5
B	Mercury Meter	30	150	5	150
C	Dry Transmitter	150	150	150	5
D	Dry Transmitter	30	150	5	150

*All connecting tubing was 3/16-inch I.D. tubing.

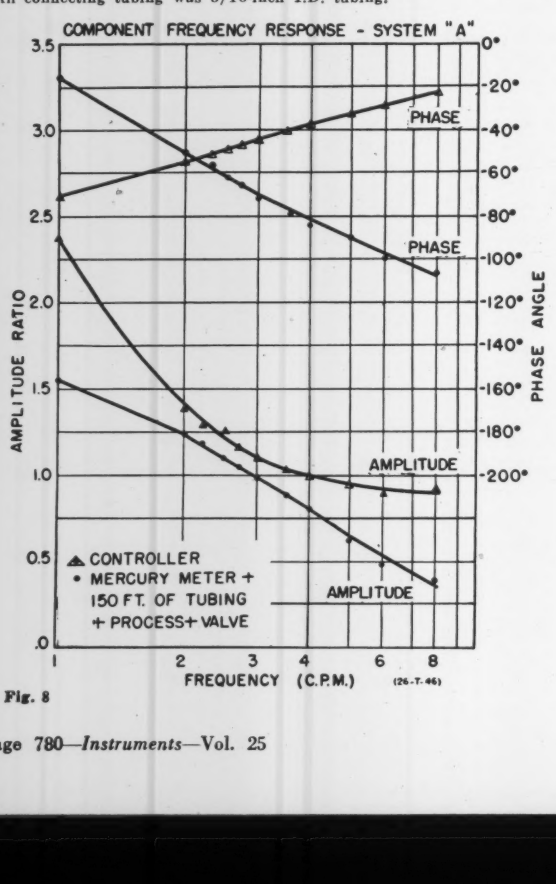

Fig. 8

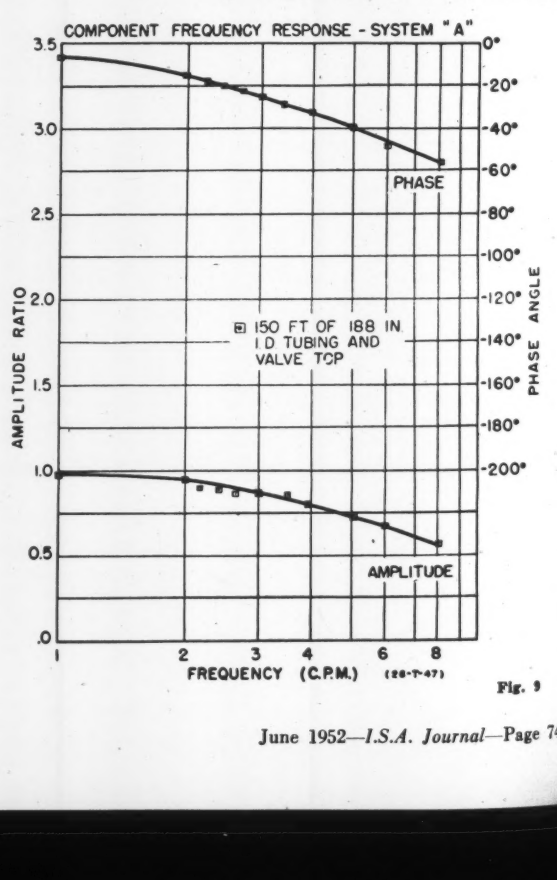

Fig. 9

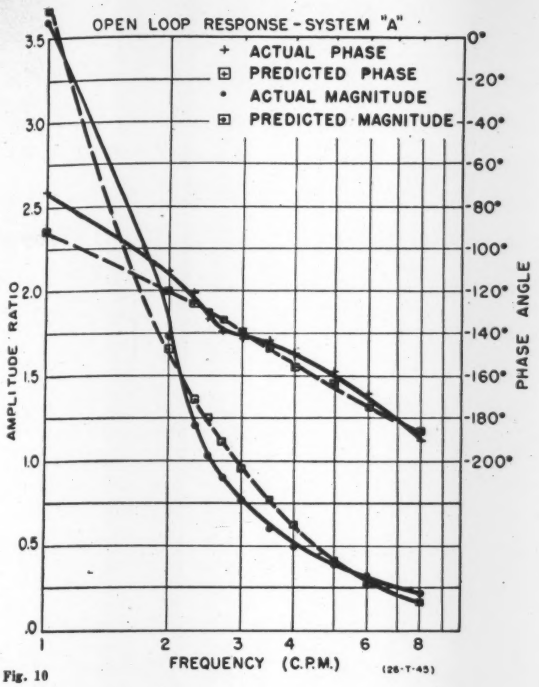

Fig. 10

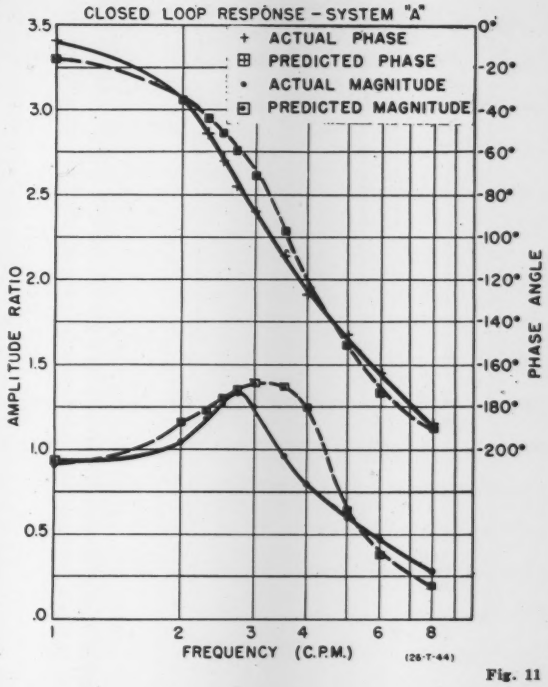

Fig. 11

at several frequencies. In this case, all inputs and outputs were in the form of pneumatic pressure signals.

The phase shift and amplitude data on the system component at different frequencies constitute the transfer function of the component. The individual transfer functions were combined using standard vector methods to give the over-all transfer function of the system (response of the system to sinusoidally varying signals of different frequencies). The predicted transfer function was then compared with the measured system transfer function to show the degree to which prediction is possible.

Test Results and Interpretation

The frequency response results on components of System "A" are shown in Figs. 8 and 9.

The system has been broken into three blocks for analysis. Fig. 8 shows the diagrams for the controller and for a second block comprised of the mercury meter plus 150 feet of tubing plus the process plus the valve. Fig. 9 shows the transfer function for a third block comprised of 150 feet of tubing and the valve top volume. These individual transfer functions were combined by multiplying amplitude ratios and adding phase angles to derive the predicted open-loop transfer function as shown in Fig. 10.

The open-loop response corresponds to the frequency response which would be obtained if the process variable line at the controller were disconnected and its signal recorded when the set point was cycled at various frequencies. The conversion from the open to closed-loop frequency response and its inverse is easily accomplished graphically or by charts and will not be discussed here.[3]

Fig. 10 shows the comparison of the actual and predicted open-loop frequency response. Note that by the use of the component curves, the source of undesirable magnitudes and phase shifts can be detected. Any unit which rapidly increases the negative phase angle of the open-loop system without a proportional decrease in amplitude ratio will contribute effective dead time to the system and decrease the system stability, thereby making control more difficult.

The prediction of the closed-loop response derived from component checks and the actual closed-loop response, as measured, are shown in Fig. 11.

Note that the measured amplitude peak is 1.35 and occurs at a frequency of 2.7 cycles per minute. Thus, from Fig. 5, the damping ratio or β is established as 0.4. The dynamic behavior of a second order system having a β of 0.4 is shown on Fig. 6. On the basis of this data, the transient response of system A, to a set point change was derived. A comparison of the derived and predicted results with the measured response curves is presented in Table II.

The methods used in analyzing the remaining systems are the same as those used for system A. Consequently, the curves will be presented in the same order and comments will be made on the closed-loop response only.

The effect of changing the component in a system is shown in System B (mercury meter with process mounted controller). The component frequency response diagrams are shown in Figs. 12 and 13.

The measured and predicted frequency response diagrams for the System B closed-loop are shown in Fig. 15. Note that by reducing the transmission lag, the negative phase angle (phase lag) was reduced and in fact levels off at approximately -140° above about 3 cycles per minute. Thus the resonant frequency has been increased from 2.7 to 3.3 cycles per minute. It should also be noted that the system stability has been increased. The result of applying the simple approximation for transient response to this system is shown in Table III. The magnification of 1.57 is representative of a β of 0.35 and the resonant frequency is 3.3 cycles per minute.

TABLE II—SYSTEM A TRANSIENT RESPONSE

Overshoot	*Actual*	*Derived from Measured Closed-Loop Frequency Response*	*Derived from Predicted Closed-Loop Frequency Response*
First Overshoot	29% at 9.6 sec	25% at 10.2 sec	35% at 9 sec
First Undershoot	12% at 16.8 sec	7% at 20.4 sec	13% at 18 sec
Second Overshoot	Very slight	1.5%	2%

TABLE III—SYSTEM B TRANSIENT RESPONSE

Overshoot	*Actual*	*Derived from Measured Closed Loop Frequency Response*	*Derived from Predicted Closed Loop Frequency Response*
First Overshoot	30% at 7.8 sec	30% at 8.4 sec	35% at 8 sec
First Undershoot	12% at 13.2 sec	10% at 16.8 sec	12% at 16 sec
Second Overshoot	Very slight	3%	5%

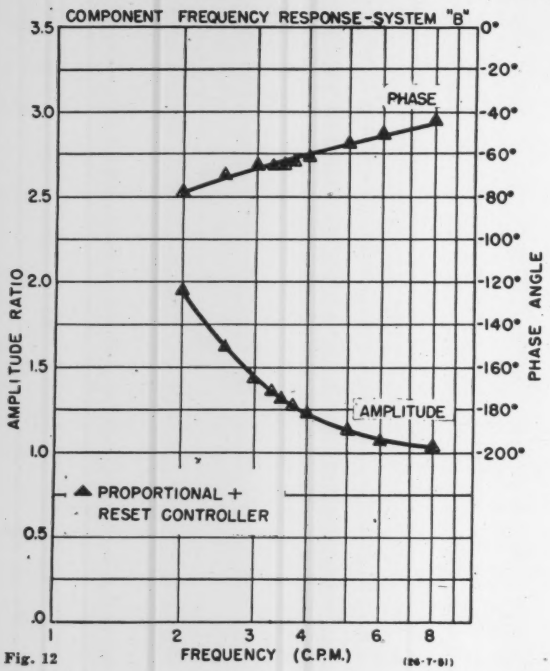

Fig. 12

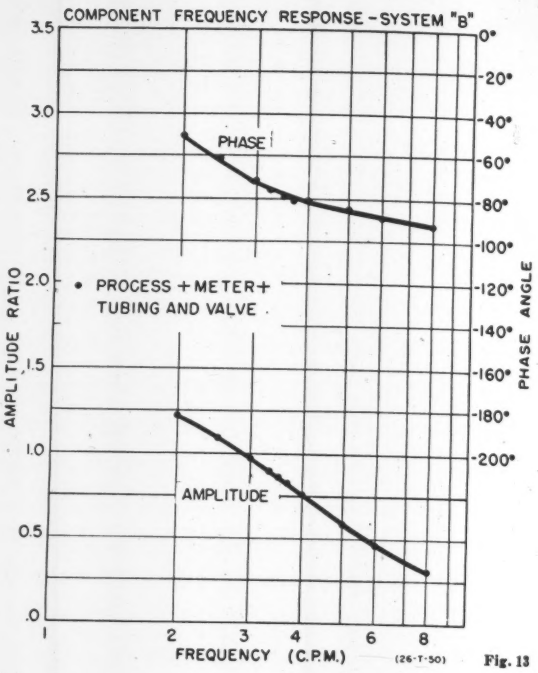

Fig. 13

In System C, the mercury meter of System A has been replaced with a dry meter. The component frequency response is shown in Fig. 16.

The actual and predicted open-loop responses of the system are shown in Fig. 17.

The measured and predicted closed-loop frequency response diagrams are shown in Fig. 18.

Note that replacing the mercury meter with a dry meter has resulted in a decrease in the phase lag of the measuring system, thus raising the resonant frequency from 2.7 cycles per minute in System A to 11 cycles per minute for System C. This system was intentionally made less stable than the other cases to illustrate the utility of the methods with a minimum amount of system damping. The measured amplitude ratio is 2.43 giving a β of 0.21. The results of applying the approximation are shown in Table IV.

Note that in this case there was a considerable error in the prediction of

TABLE IV—SYSTEM C TRANSIENT RESPONSE

Overshoot	*Actual*	*Derived from Measured Closed Loop Frequency Response*
First Overshoot	45% at 3 sec	51% at 2.7 sec
First Undershoot	26% at 5.5 sec	20% at 5.6 sec
Second Overshoot	14% at 8.2 sec	12% at 7.8 sec

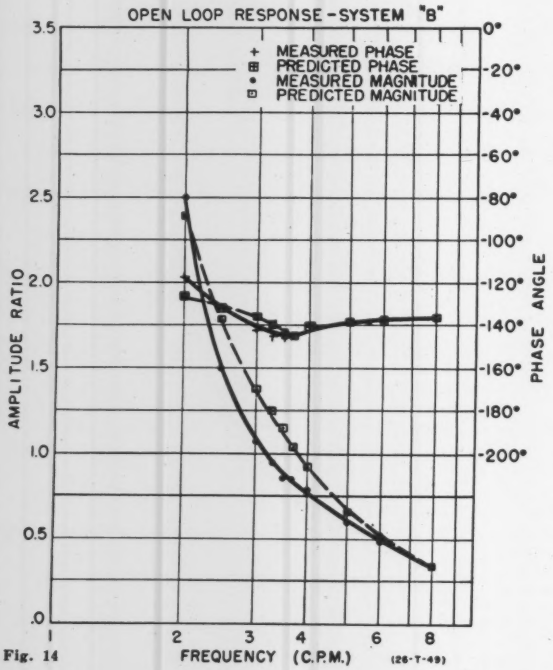

Fig. 14

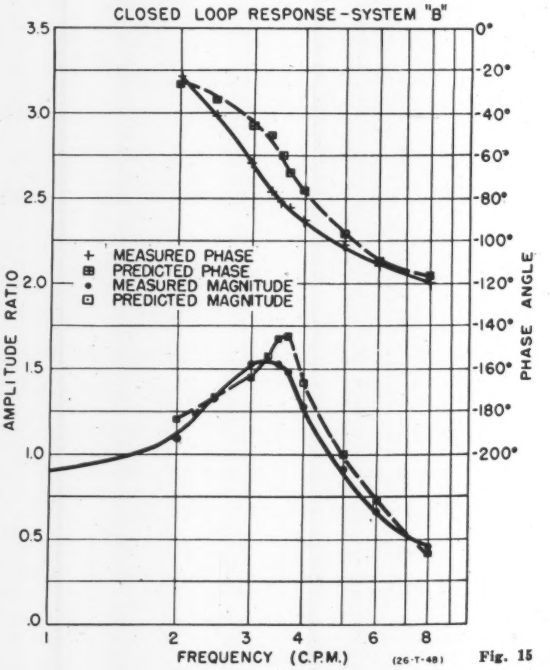

Fig. 15

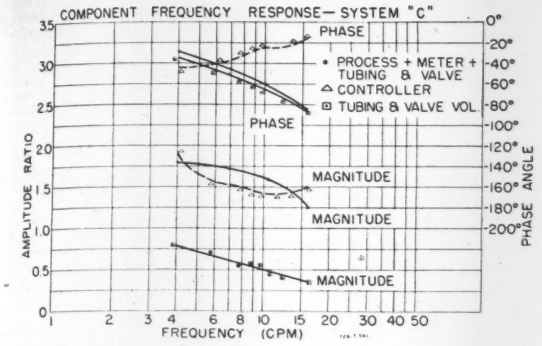

Fig. 16.

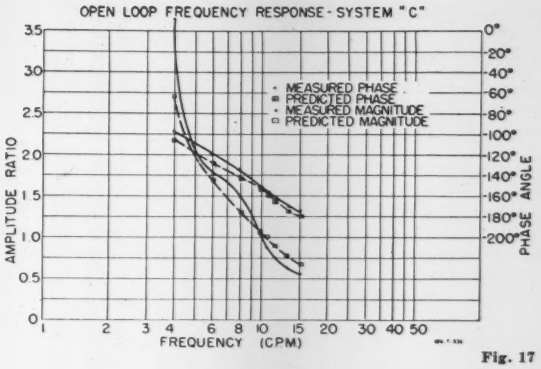

Fig. 17

resonance. This was due to the low damping used on the system. It also emphasizes the need for accurate measurements where several component transfer functions are to be combined.

An examination of System D illustrates the effect of removing transmission lag in a fast flow control loop. The component frequency response is shown in Fig. 19. The smaller phase lag shown in the open-loop frequency response diagram on Fig. 20 indicates a much faster recovery from transients.

In this case the dynamic behavior of the system, with high gain settings on the controller and under conditions of sudden changes in set point pressure, was influenced to a considerable degree by the non-linearities of the components within the control loop. It was found, however, that the linearity of the system could be improved by adjusting the controller settings for a slightly overdamped system response. The closed-loop frequency response is shown in Fig. 21.

Note that no amplitude peak occurred in the plot of the relation between amplitude ratio and frequency.

This illustrates a case where there is a breakdown in the simple methods of examining the frequency response in the region of resonance, used in the first three examples. From the open-loop frequency response, however, some observations can be made as to the system performance. If the open-loop frequency response curves of Systems C and D are compared, a decrease of phase lag and attenuation for the same frequency range is noted in System D. A decrease in phase lag and attenuation is indicative of faster recovery to the control point following an upset.

Summary and Conclusions

The four examples covered indicate that the servo analysis methods can be applied to process control problems to obtain useful and reasonably accurate predictions of performance. The application of graphical methods (based on a simple system) has been illustrated, and some means for the comparative evaluation of more camplicated systems have been mentioned. Obviously, for maximum utility of frequency response data, the information must be evaluated in the light of previous control and process experience. It supplements but does not replace experience.

The development of this technique is in its early stages. An examination of the blocks to be analyzed shows that some are under the jurisdiction of process designers and plant operators while others are the responsibility of the instrument manufacturers. The success of the program will be dependent upon the extent to which all three participate. Naturally, there will be limitations of the method. These can be overcome only as they are met.

When the methods have been exploited, they can reasonably be expected to perform many useful functions. Among these are:

(1) To permit prediction of system

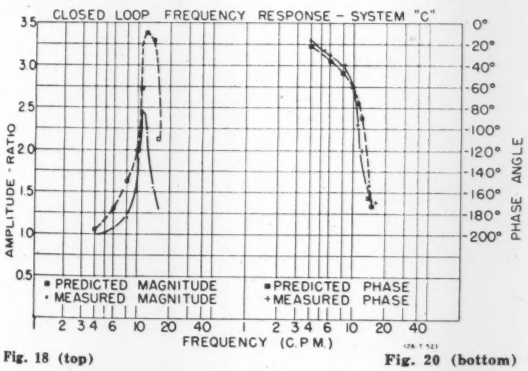

Fig. 18 (top)

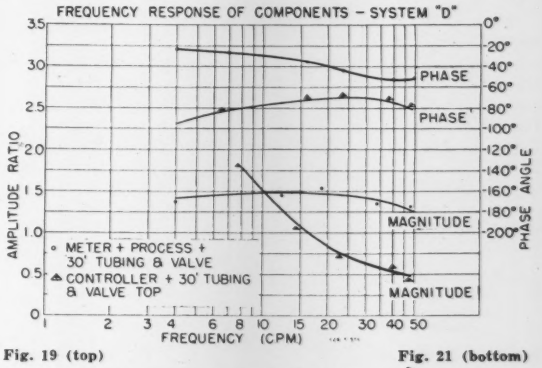

Fig. 19 (top)

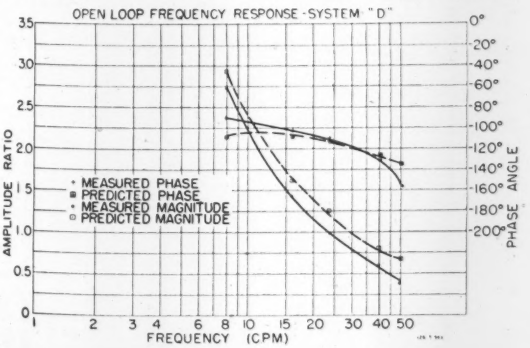

Fig. 20 (bottom)

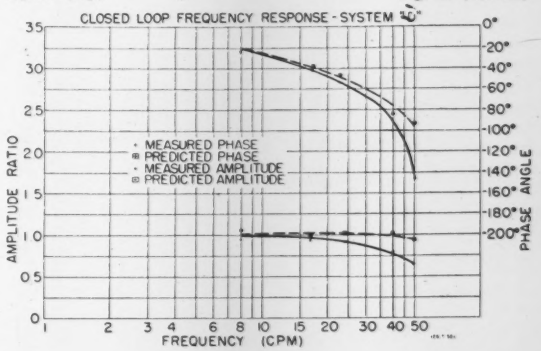

Fig. 21 (bottom)

performance to be made from tabulated information on the individual components of the system.

(2) To establish the necessary response characteristics which an instrument or process being designed must have in order to make the complete system into which it is installed operate as desired.

(3) To assist the designer in determining the source of undesirable effects and to permit minimizing their effect, either by a change in process or instrumentation or by intelligent compromises.

(4) To permit comparison of the performance of various processes as well as other components where a number of choices are available.

(5) To provide a means of cataloging previous experience.

(6) As information is gained, valuable predictions as to "noise" effects on a process and how processes can be improved can be obtained directly from the transfer function. Naturally, practical experience is of tremendous importance for this type of work.

(7) Predictions of performance can be made, so that in the selection of equipment, performance may be discussed along with the other important factors such as the economics, convenience, maintenance, servicing, etc.

It is not expected that all systems will prove as simple to analyze and test as the system chosen. The authors, however, present this data in the hope that others may be encouraged to investigate and publish results on the use of the methods, thus furthering their use as an engineering tool for process work.

The authors wish to express their appreciation to E. C. Grogan for his asistance in assembling the test data.

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Gas Measurement Committee Report

By F. M. PARTRIDGE, Southern California Gas Company

THE Joint A.G.A.-A.S.M.E. Orifice Meter Committee was formed in 1948 for the purpose of developing further information on the installation requirements of orifice meters. Particular attention was to be directed towards the following:

1. Effects of plug valves, globe valves and elbows on the inlet side of the orifice.
2. Comparison of orifice meter fittings with the older type of flange mountings.
3. Effects of interior roughness of meter runs.

Test work directed toward developing the desired information has been conducted at Rockville, Maryland during the summers of 1949, 1950 and 1951 at the Naval Boiler and Turbine Laboratory, Philadelphia Naval Base during 1949 and 1950, and in the Hydraulics Laboratory of the National Bureau of Standards during the winter of 1950-51.

While it has been the intention of the Committee to issue progress statements, including summaries of test results, it does not intend to issue any report involving conclusions or recommendations until after all of the necessary test work has been completed and the results carefully evaluated. In line with this policy no conclusions or recommendations are offered at this time.

The tables of orifice coefficients in Gas Measurement Committee Report No. 2 do not specifically (and may not actually) apply to meters over 15 inches O.D. The growing need for an experimental basis for the extension of the tables to larger meters, 30 inches O.D. or over, has been called to the attention of the A.G.A.-A.S.M.E. Committee repeatedly. Therefore, at its meeting last May, the Committee decided to extend its program so as to provide the basis for an extension of the coefficient tables.

A special subcommittee on large orifice meters was appointed under the chairmanship of Mr. E. E. Stovall, Lone Star Gas Company, to conduct this work. A very considerable amount of work has been done in determining a satisfactory location for the tests, designing the necessary installation, and obtaining required materials.

The tentative location selected for the test work is at Main Line Valve No. 21 of the Tennessee Gas Transmission Line in Harris County, Texas. The proposed installation which includes a pair of 30-in. orifice flanges, eight 10-in. orifice meters to serve as a reference, and a 30-in. senior orifice fitting is shown in Fig. 1. The headers for the eight 10-in. meters are of the continuous pattern in order to provide better balance of the flow through the different tubes. All of the meter runs were designed so as to be geometrically similar and valves were omitted as much as possible in order to avoid effects of turbulence. The test meters are to be provided with flange taps, pipe taps and special taps at ⅛ pipe diameter from the plate. It is planned to start construction of these meters in the near future and perhaps conduct test work during the coming summer. Final reports presenting conclusions and recommendations as a result of the current A.G.A.-A.S.M.E. project will probably be available about the end of this year.

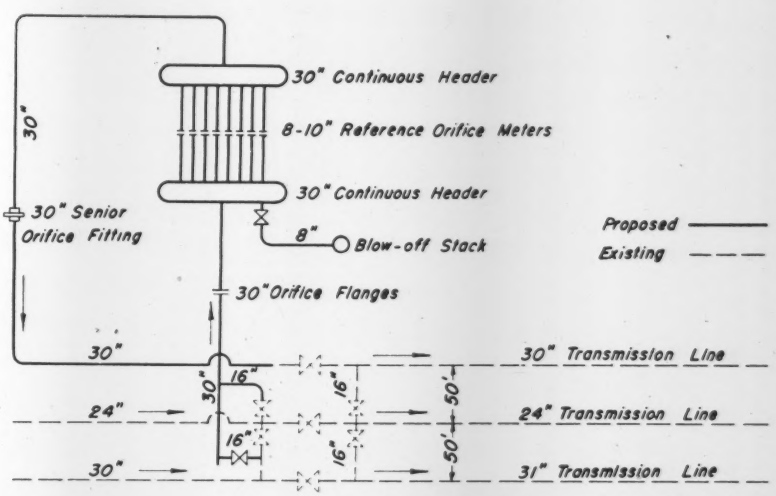


Fig. 1. Proposed experimental 30-in. meter, Harris County, Texas; Tennessee Gas Transmission line at main line valve 21.

Determination of Deviation Factors for Natural Gas

At the A.S.M.E. meeting at Atlantic City last November a paper was presented titled "Progress Report on the Study of Supercompressibility Factors for Natural Gases" by Richard H. Zimmerman and Samuel R. Beitler of Ohio State University.

This paper reported dissatisfaction with existing methods for predicting deviation factors at pressures above 500 psi. A Supercompressibility Research Group was set up under the sponsorship of the Tennessee Gas Transmission Company and Columbia Gas System with other companies having the privilege to participate at any time.

The complete program is to develop

Presented at the June 1952 meeting of the Southern California Meter Association.

accurate correlation of experimental deviation factors furnished by the Research Group. It is to cover natural gases for pressures of 0-4000 psig., using the various specific gravities, fractional analyses and temperatures as indexes. The method adopted is based on the one proposed by R. V. Dunkle based on the use of methane as the principal constituent of a natural gas mixture. (See Proc. P.C.G.A. Vol. 35, 1944, page 80.)

A working method has been developed which up-to-date covers the following ranges:

Pressures—	0 to 1100 psig.
Diluents—	0 to 20 percent
Gravities—	0.55 to 0.75
Temperatures—	40 to 200 deg. F.

Resulting F_{PV} factors are stated to be within 0.10 percent of actual test values.

A comparison of the difference from actual test values of the Research Group Method and the C.N.G.A. Method is shown in Fig. 2. The maximum difference found using the C.N.G.A. Method was 0.0028 while using the Research Group Method it was only 0.0006. The average difference using the C.N.G.A. Method was 0.001 while using the Research Group Method the average was only 0.00031. These results are based on a sample of Texas Gas tested by the Southern Counties Gas Company.

Research Method

Deviation factors are determined in the following manner:

The pseudo-critical absolute temperature, T_c, and pseudo-critical absolute pressure, P_c, of the gas mixture are computed using the formulas:

$$T_c = 127.0 + 92.10\,G + 243.2X_c + 0.1642H$$

$$P_c = 670.8 - 184.8G + 681.9X_c + 0.1033H$$

$$T_R = \frac{T_{abs.}}{T_c} \qquad P_R = \frac{P_{ga.}}{P_c}$$

Nomenclature:

F_{PV} = Deviation (Supercompressibility) factor. 14.4 psia. base.

G = Specific gravity of gas mixture.

X_c = Mol percent carbon dioxide divided by 100.

H = Gross heating value, dry basis, Btu per cubic foot at 60 F. and 14.73 psia.

T_c = Pseudo-critical absolute temperature, degrees F.

P_c = Pseudo-critical absolute pressure, pounds per square inch.

T_R = Reduced absolute temperature.

P_R = Reduced gage pressure.

$T_{abs.}$ = Absolute temperature of gas.

$P_{ga.}$ = Gage pressure of gas.

With T_R and P_R known the F_{PV} factor is determined from Table I—Supercompressibility Factors, F_{PV}, for Pure Methane.

Deviation factors determined as above were compared with results of 393 tests reported in the Research Group Report.

Linear interpolation of data will introduce a deviation no greater than 0.01 percent from a plotted curve of the listed data.

While only 5 tests were run above 1100 pounds pressure results indicated no significant deviation in results. Results of the 5 tests which extended to 2200 psi. showed that out of 41 points only 2 deviated more than 0.001 from the test results.

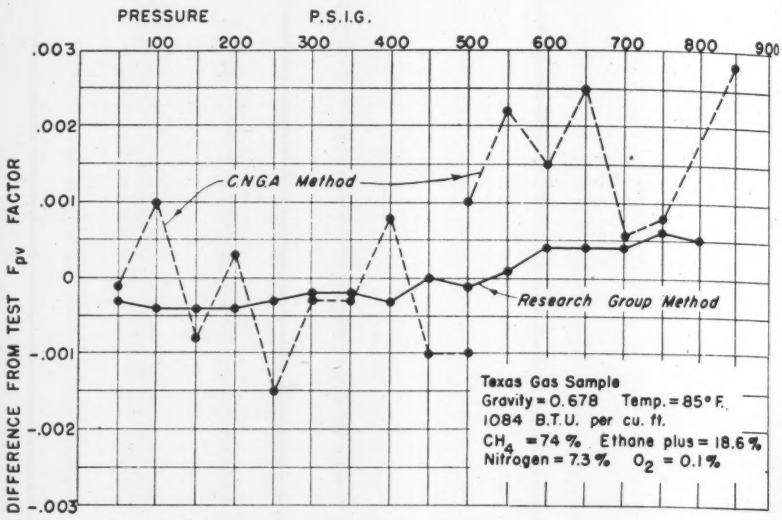


Fig. 2. Comparison of methods for determining deviation factors.

TABLE I—SUPERCOMPRESSIBILITY FACTORS F_{PV} FOR PURE METHANE

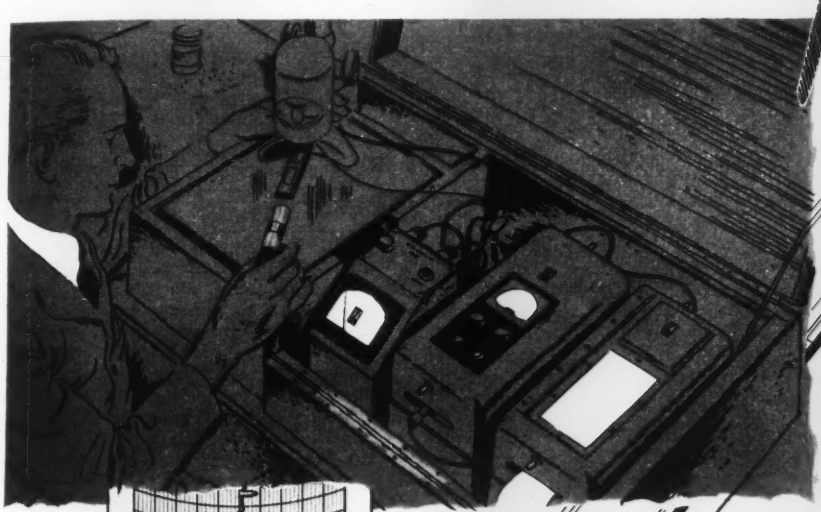
Reduced Gage Pressure P_R	Reduced Temperature T_R 1.16	1.18	1.20	1.22	1.24	1.26	1.28	1.30	1.32	1.34	1.36
0.2	1.0254	1.0237	1.0223	1.0210	1.0198	1.0186	1.0176	1.0167	1.0158	1.0150	1.0142
0.4	1.0512	1.0481	1.0452	1.0425	1.0400	1.0375	1.0354	1.0334	1.0315	1.0298	1.0282
0.6	1.0795	1.0743	1.0696	1.0652	1.0612	1.0574	1.0540	1.0509	1.0480	1.0453	1.0429
0.8	1.1122	1.1037	1.0964	1.0896	1.0839	1.0786	1.0737	1.0693	1.0651	1.0613	1.0577
1.0	1.1525	1.1393	1.1277	1.1176	1.1092	1.1017	1.0948	1.0888	1.0831	1.0780	1.0734
1.2	1.2006	1.1802	1.1631	1.1489	1.1317	1.1265	1.1172	1.1093	1.1021	1.0957	1.0896
1.4				1.1835	1.1667	1.1527	1.1411	1.1310	1.1219	1.1139	1.1063
1.6					1.1972	1.1804	1.1657	1.1532	1.1418	1.1317	1.1226
1.8							1.1926	1.1766	1.1622	1.1496	1.1385
2.0								1.1970	1.1807	1.1662	1.1533
2.2									1.1961	1.1811	1.1675
2.4										1.1944	1.1798
2.6											1.1907
2.8											1.1993

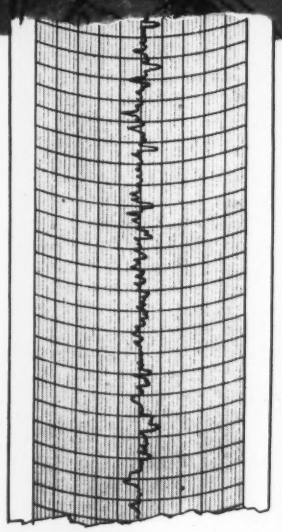
Reduced Gage Pressure P_R	Reduced Temperature T_R 1.38	1.40	1.42	1.44	1.46	1.48	1.50	1.52	1.54	1.56	1.58
0.2	1.0134	1.0125	1.0119	1.0112	1.0106	1.0100	1.0095	1.0090	1.0085	1.0082	1.0078
0.4	1.0267	1.0253	1.0240	1.0226	1.0214	1.0202	1.0191	1.0181	1.0171	1.0163	1.0155
0.6	1.0405	1.0384	1.0362	1.0342	1.0324	1.0306	1.0289	1.0275	1.0260	1.0245	1.0233
0.8	1.0545	1.0513	1.0484	1.0458	1.0433	1.0410	1.0388	1.0367	1.0348	1.0330	1.0312
1.0	1.0690	1.0650	1.0612	1.0573	1.0544	1.0515	1.0487	1.0461	1.0437	1.0414	1.0392
1.2	1.0840	1.0788	1.0740	1.0696	1.0656	1.0618	1.0583	1.0550	1.0520	1.0492	1.0465
1.4	1.0994	1.0930	1.0870	1.0816	1.0768	1.0723	1.0680	1.0640	1.0605	1.0570	1.0539
1.6	1.1142	1.1067	1.0997	1.0932	1.0874	1.0820	1.0771	1.0725	1.0684	1.0644	1.0607
1.8	1.1286	1.1199	1.1119	1.1045	1.0977	1.0915	1.0859	1.0808	1.0710	1.0716	1.0674
2.0	1.1423	1.1323	1.1234	1.1153	1.1078	1.1010	1.0947	1.0890	1.0836	1.0786	1.0740
2.2	1.1552	1.1438	1.1340	1.1250	1.1168	1.1094	1.1025	1.0960	1.0901	1.0846	1.0795
2.4	1.1665	1.1545	1.1438	1.1340	1.1250	1.1172	1.1099	1.1032	1.0969	1.0908	1.0850
2.6	1.1765	1.1636	1.1517	1.1414	1.1321	1.1236	1.1158	1.1088	1.1020	1.0957	1.0898
2.8	1.1847	1.1712	1.1588	1.1475	1.1376	1.1288	1.1206	1.1132	1.1061	1.0996	1.0935
3.0	1.1905	1.1765	1.1639	1.1521	1.1412	1.1322	1.1238	1.1164	1.1092	1.1024	1.0961

Reduced Gage Pressure P_R	Reduced Temperature T_R 1.60	1.62	1.64	1.66	1.68	1.70	1.72	1.74	1.76	1.78	1.80
0.2	1.0074	1.0070	1.0065	1.0063	1.0060	1.0056	1.0054	1.0050	1.0049	1.0046	1.0044
0.4	1.0148	1.0140	1.0133	1.0125	1.0119	1.0114	1.0108	1.0102	1.0098	1.0093	1.0089
0.6	1.0221	1.0210	1.0200	1.0190	1.0180	1.0171	1.0163	1.0154	1.0146	1.0138	1.0130
0.8	1.0295	1.0280	1.0266	1.0253	1.0240	1.0227	1.0210	1.0205	1.0194	1.0185	1.0174
1.0	1.0371	1.0351	1.0333	1.0315	1.0299	1.0284	1.0269	1.0255	1.0241	1.0229	1.0216
1.2	1.0441	1.0419	1.0396	1.0375	1.0355	1.0335	1.0318	1.0301	1.0285	1.0270	1.0254
1.4	1.0510	1.0482	1.0456	1.0432	1.0409	1.0386	1.0365	1.0346	1.0327	1.0310	1.0291
1.6	1.0574	1.0543	1.0514	1.0486	1.0459	1.0434	1.0411	1.0388	1.0365	1.0345	1.0324
1.8	1.0635	1.0600	1.0569	1.0537	1.0508	1.0481	1.0455	1.0429	1.0404	1.0380	1.0356
2.0	1.0695	1.0655	1.0618	1.0583	1.0551	1.0521	1.0492	1.0465	1.0439	1.0413	1.0387
2.2	1.0748	1.0705	1.0665	1.0626	1.0591	1.0558	1.0526	1.0496	1.0469	1.0440	1.0412
2.4	1.0788	1.0750	1.0705	1.0664	1.0625	1.0589	1.0556	1.0524	1.0494	1.0465	1.0435
2.6	1.0842	1.0791	1.0742	1.0699	1.0657	1.0618	1.0581	1.0547	1.0515	1.0484	1.0451
2.8	1.0877	1.0825	1.0773	1.0727	1.0684	1.0643	1.0605	1.0568	1.0534	1.0500	1.0466
3.0	1.0901	1.0844	1.0795	1.0750	1.0705	1.0663	1.0625	1.0586	1.0549	1.0513	1.0478

"There is measure in all things; certain limits, beyond and short of which right cannot be found"

—Horace





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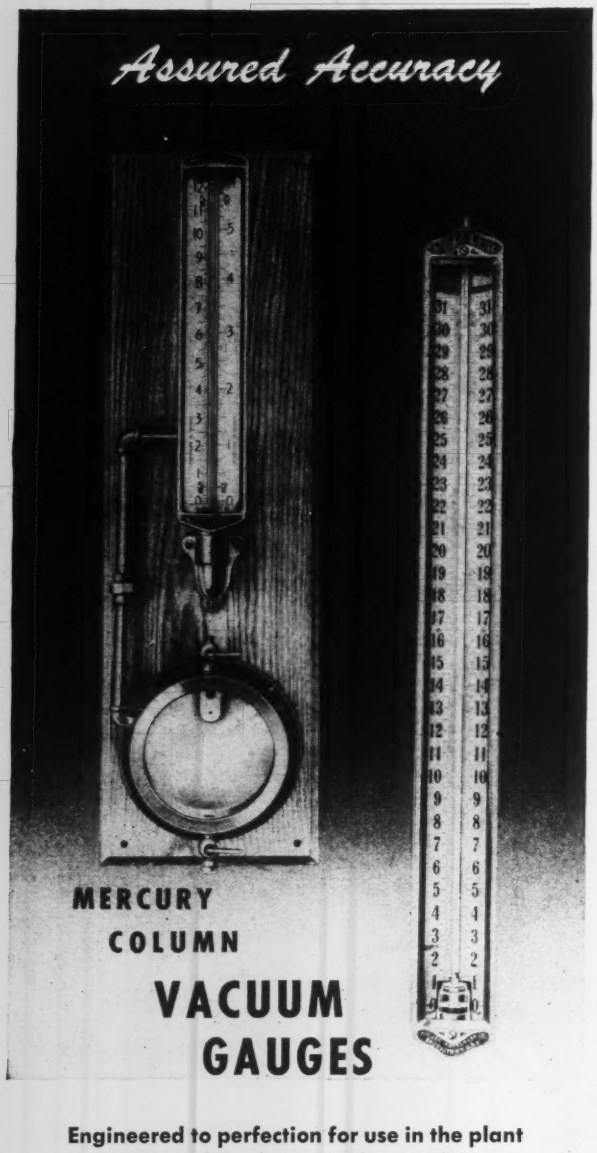

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Continued from page 768

tial of the tube, at which point the gas deionizes and the capacitor starts charging again. Thus the amplitude limits of the output sawtooth waveform are the ionizing and deionizing potentials of the tube and cannot be altered. The frequency (number of sawtooth waveforms per second) is controlled by the adjustment of either R, C, or supply voltage. The frequency can be increased by decreasing R or C, or by increasing the supply voltage.

Thyratron Sawtooth Generator

A relaxation oscillator that uses a thyratron instead of a neon tube is shown in Fig. 10-16. The circuit action is the same as for the neon oscillator; however, the grid of the thyratron offers convenient control of the firing potential and thus of the amplitude of the generator output.

A disadvantage of the thyratron is that when the grid bias is changed to control the firing potential of the tube, the frequency changes also. The frequency can be changed without affecting the amplitude by changing the charging resistor, capacitor, or voltage, as in the neon sawtooth generator.

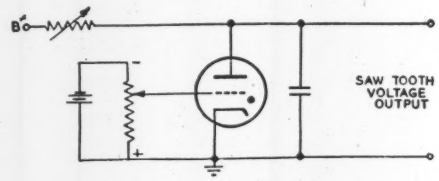

Fig. 10-16. Thyratron sawtooth generator.

In addition to amplitude control, another advantage of the thyratron is that the firing can be *synchronized* (stabilized) by an external (sync) signal of high stability. When the sync signal (usually a sine wave) is applied to the grid, the firing potential can be altered slightly; the tube then fires at one point on the applied sync signal. The sync signal can stabilize the generator only at a frequency that is higher than the natural frequency without synchronization because the sync voltage can make the thyratron fire sooner, but not later, than its natural frequency. The generator can be synchronized, or *locked*, to the same frequency, to a submultiple, or to a multiple of the injected sync voltage.

Note that the output waveform of a relaxation-type sawtooth generator is a capacitor-charging voltage. Thus the output has an exponentially rising shape. By using a d-c. supply voltage that is much higher than the firing voltage of the tube, a fairly linear rise can be obtained.

The Multivibrator

The multivibrator is a form of relaxation oscillator that is used frequently in switching and timing circuits. It produces a square-wave output and is called a square-wave generator or electronic switch. There are two types—free-running and driven. The former oscillates continuously and without synchronization; the latter is controlled by an external synchronizing voltage.

The basic free-running multivibrator is shown in Fig. 10-17. Note that the plate of each tube is connected to the grid of the other through a capacitor.

Assume a small negative signal on the grid of V_1. This causes a positive amplified signal at the plate of V_1. This signal causes a further amplified negative signal at the plate of V_2, which is fed back to the grid of V_1. This action causes the grid of V_1 to go far negative quickly and cut off the tube, at which time there is no signal at its plate. The negative charge on the grid of V_1 now leaks off through R_1. As soon as the cut-off point is reached, plate current starts to flow, starting another half cycle of operation. Thus each tube is alternately full conducting and then cut off. As the circuit is not in equilibrium in either condition, the process keeps repeating with a period

Fig. 10-17. Basic multivibrator.

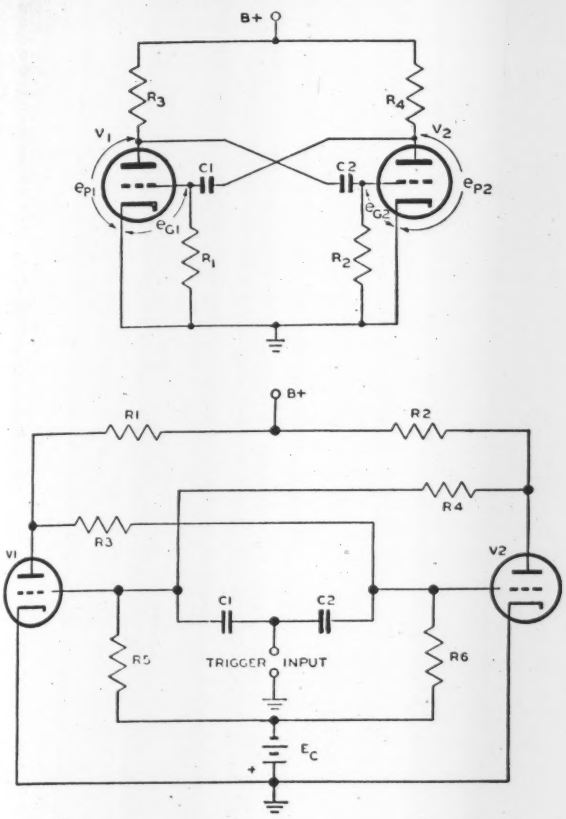

Fig. 10-18. Eccles-Jordan flip-flop trigger circuit.

determined by the R_1C_1 and R_2C_2 time constants. The output waveform at the plate of either tube is similar to a square wave. When R_1C_1 and R_2C_2 are the same, the square wave is symmetrical—that is, of equal duration on each half cycle of operation.

Synchronization

As the frequency-stability of the free-running multivibrator is poor, multivibrators in timing and sweep circuits usually are *driven*—that is, synchronized by an external waveform. A stable sine wave or an accurately timed series of pulses can be applied to the cathode or grid of either tube. The synchronizing voltage causes the tube to "switch" at one point on the applied sync signal, thus locking the multivibrator to the frequency of the applied signal.

The multivibrator can be synchronized to a fraction (one half, one third, etc.) of the driving frequency. This permits *frequency division.*

Eccles-Jordan Flip-flop Trigger Circuit

The Eccles-Jordan trigger circuit (Fig. 10-18) is a basic trigger circuit that has two conditions of equilibrium. A positive or negative trigger pulse causes the circuit to "flop" from one condition to the other.

The circuit is similar to the basic multivibrator, except that the plate of each tube is connected to the grid of the other tube through a resistor. Thus the d-c. grid potential depends on the plate potential.

If V_1 is nonconducting, its plate is at a high potential. This causes the grid of V_2 to be very positive and V_2 to be conducting. This is one of the two equilibrium conditions.

A positive trigger causes nonconducting V_1 to conduct slightly. This causes a negative plate signal at V_1 and a larger positive plate signal at V_2. This regenerative action quickly causes V_1 to become conducting and V_2 to

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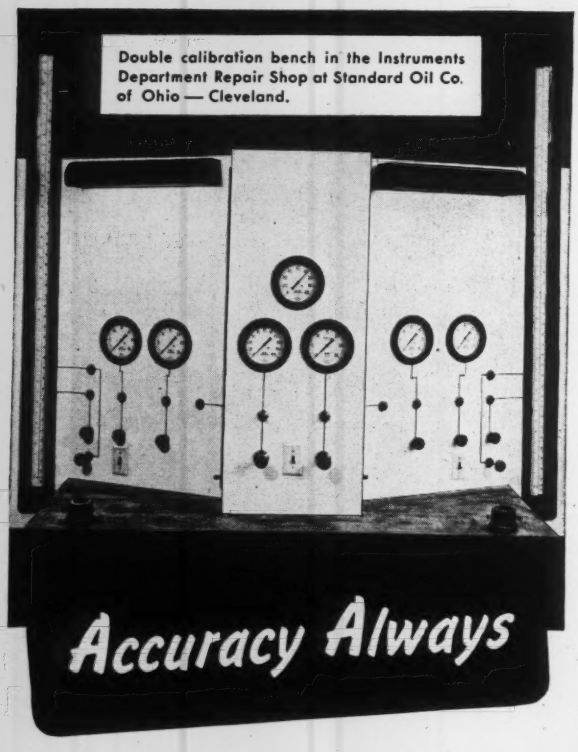
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be nonconducting. This is the other equilibrium condition. Another positive trigger acts on V_2, starting another "flip-flop" of the circuit. The flip-flop action is the same as in the multivibrator.

A negative trigger also can cause flip-flop action because it affects the conducting tube, causing a decrease in plate current and the initiation of flip-flop trigger action.

As two pulses are required for a complete cycle, the circuit is a scale-of-two counter. It is used in this way in modern digital computers, which use binary (scale-of-two) counting.

Beat-Frequency Oscillators

A basic use of oscillators is changing the frequency of a sine wave by heterodyning. *Heterodyning* refers to the mixing of two sine waves of different frequency. When two such waves are fed into a nonlinear device (such as an unbiased tube or a diode), the output contains not only the two input frequencies, but also frequencies equal to the *sum* and *difference* of the two input frequencies. Thus a wave of any frequency can be heterodyned to a lower or higher frequency without altering its amplitude configurations.

This principle is used in all superheterodyne radio receivers and in the beat-frequency oscillator (BFO). In the superheterodyne receiver, the radio-frequency signal is lowered to an intermediate frequency by heterodyning the r-f. carrier wave with a signal from a local oscillator in

Fig. 10-19. Simplified schematic of beat-frequency oscillator.

the receiver. The lower intermediate-frequency signal then is amplified and demodulated into audio-frequency signals.

In the beat-frequency oscillator (Fig. 10-19), two high-frequency oscillators are heterodyned. The difference frequency, or *beat frequency*, in the output can be a low-frequency audio signal. By changing one of the oscillators, a large percentage change in frequency of output is obtained.

In order to produce sum or difference frequencies by heterodyning two frequencies, it is necessary that the mixing device be nonlinear—that is, a better conductor in one direction than in the other. A diode or an amplifier tube with a nonlinear characteristic can be used. Special tubes with several grids for mixing signals are called mixers, or pentagrid converters.

Shock-Excited Oscillator

Fig. 10-20 shows a resonant tank in the cathode circuit of a tube. As the grid is at a positive potential, the tube is normally conducting.

If a large negative signal is applied at the input, the plate current is interrupted suddenly. The resonant tank then is *shocked* into oscillation, which gradually dies out—that is, the output is a damped oscillation. The oscillator sometimes is called a *ringing* oscillator.

The circuit would provide an output if the tube were non-conducting and if a positive pulse were applied at the input. However, the oscillation would die out more rapidly because the low conducting plate-resistance of the tube is effectively in parallel with the tank. When the tube is suddenly cut off, the tube is a high resistance in parallel with the tank and does not provide much damping.

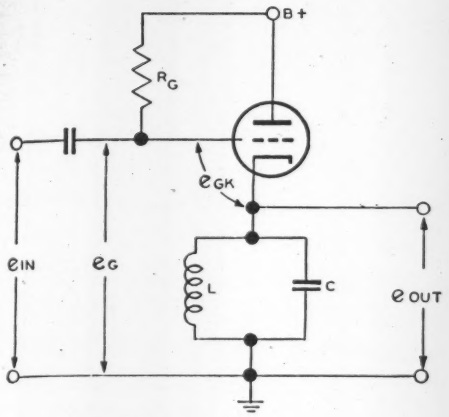

Fig. 10-20. Shock-excited oscillator.

The circuit is used in timing and radar applications by applying an accurately timed negative pulse (called a *gate* pulse) at the input. Thus a precise number of oscillations can be obtained for the duration of the gate pulse.

UHF Oscillators

Resistance-capacitance oscillators and beat-frequency oscillators can produce audio frequencies. Crystal-controlled and magnetostriction oscillators can produce ultrasonic frequencies. Oscillators with conventional parallel-resonant *L-C* tanks operate satisfactorily up to about 100 Mc.; above this frequency, however, the capacitance and inductance become too small for practical use.

Butterfly Tanks

Above 100 Mc., the inductor can be made into a single turn, and the rotor plates of the capacitor can be shaped like a butterfly, as in Fig. 10-21. Motion of the rotor plates fills the air space and varies both the inductance and the capacitance. Thus the arrow depicting variation in Fig. 10-21 covers both the inductor and capacitor. Butterfly

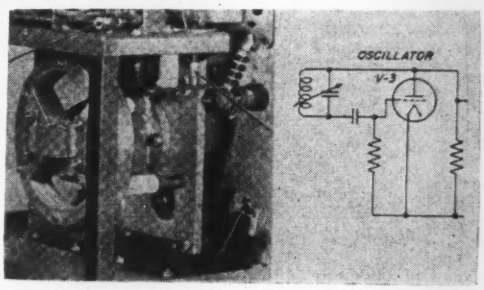

Fig. 10-21. Butterfly-tank and symbol in ultraudion circuit.

Fig. 10-22. Cavity resonator.

tanks are used with acorn and doorknob tubes (see Chapter 5) for frequencies up to several thousand megacycles. Above this frequency special tubes that utilize electron transmit time (Klystrons and magnetrons) are used with cavity resonators as the resonant element.

Cavity Resonators

Cavity resonators are the resonant tanks used at microwave frequencies—that is, above 1000 Mc. The most common type resonant cavity is the *reentrant cavity*, shown in Fig. 10-22.

The term "reentrant" refers to the fact that a section of the cavity is directed inward and made narrow. The narrow section is made of a grid or lattice so that electrons can pass through. If electrons pass through in bunches,

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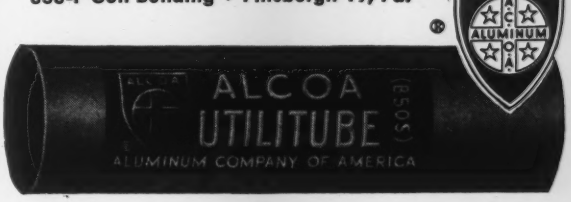

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they excite electromagnetic oscillation in the cavity. The shape and size of the cavity determine the resonant frequency; the reduced section is primarily capacitive, the outer volume is primarily inductive. A tuning method consists of changing the width of the capacitive gap. The name "Rhumbatron" or rhumbic enclosure is used sometimes to identify resonant cavities. This name is a trademark of Sperry Gyroscope Co.

In order to excite oscillation in the cavity, electrons must pass through or near the gap at appropriate intervals. Electron transit time from cathode to plate, which is the factor that prevents conventional tubes from operating at microwave frequencies, thus is utilized to produce oscillation. Klystron and magnetron oscillators often are constructed with built-in cavity resonators.

The principle of operation of all velocity-modulated tubes, Klystrons and magnetrons, is interaction of the electron beam and the electromagnetic field produced in the resonant cavity. As electrons pass near the cavity, oscillation (electromagnetic field) is induced in the cavity. This field acts on the electrons, accelerating electrons on positive peaks and decelerating them on negative peaks. It is this interaction between field and electrons that produces electron bunches. The bunches then produce strong oscillations when they sweep through the cavities.

Klystron

Fig. 10-23 shows the operation of a Klystron. Electrons leave the cathode and travel through the buncher and catcher cavities. As they pass through the first reduced section, or *buncher* grids, they induce a resonance in the first (buncher) cavity. As the electrons travel through the *drift space*, slow electrons lag behind fast electrons and

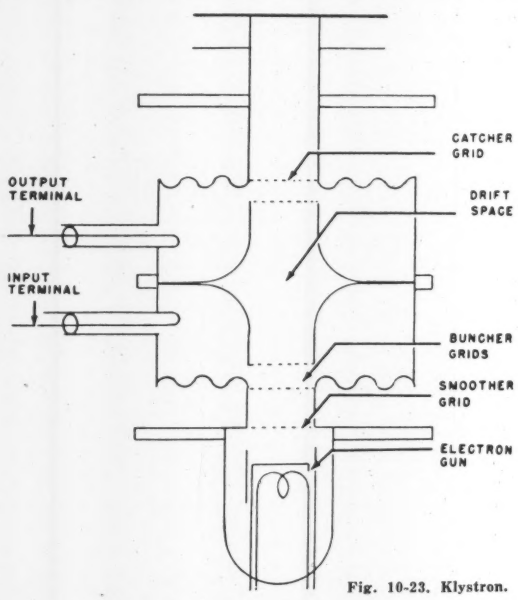

Fig. 10-23. Klystron.

groups of electrons are formed. The groups pass through the catcher grids and excite strong oscillation in the upper (catcher) cavity. This cavity provides both the output and feedback signal. When feedback from the output to the input terminal is of proper polarity, a microwave oscillation is sustained. The first cavity is called a buncher because it causes the bunching of electrons in the drift space.

In the *reflex Klystron*, a negative plate repels the bunches so that they pass through the single cavity in the opposite direction. Thus one cavity serves as both buncher and catcher. This type is used widely as a local oscillator in UHF radar receivers.

Magnetron

The magnetron, like the Klystron, is a velocity-modulated vacuum tube that uses motion of electron bunches to induce

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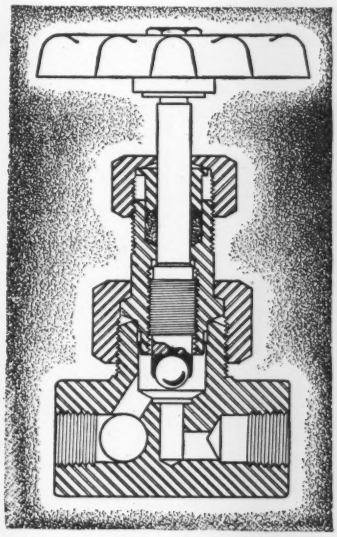

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oscillations in a microwave resonant cavity. However, the bunches of electrons are formed by bending the electron beam with a strong magnetic field directed perpendicular to the direction of motion of the electrons, as shown by the arrow in the symbol for the magnetron (Fig. 10-24). The magnetic field causes the electrons to travel in a cyclical

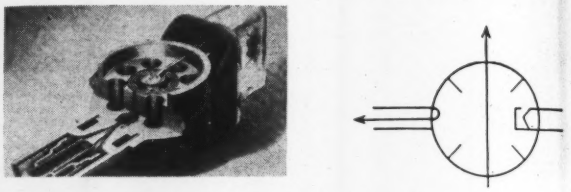

Fig. 10-24. Magnetron and symbol.

path, as shown in Fig. 10-25. As the electrons pass the openings leading to the resonant cavities, they induce oscillation in the cavities. The electromagnetic field in turn causes the electrons to form bunches. The electron bunches travel in cyclical paths from cathode to anode and also rotate around the cathode. They pass each opening to each resonant cavity at the proper instant to induce and sustain

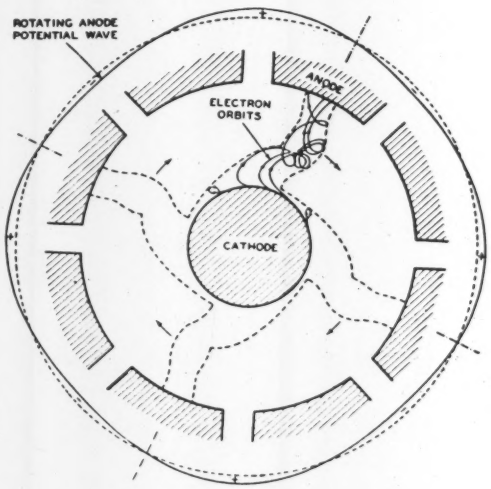

Fig. 10-25. Path of electrons in magnetron.

oscillation in the cavity. The output is taken from a small pickup loop brought near one of the cavities. Strong oscillations are developed in the cavities, which are a part of the anode block of the magnetron.

The magnetron is particularly useful as a generator of high-power pulses of microwave energy. It is the source of high-power pulses of UHF energy in most military and navigation radars.

TEST ITEMS—X. OSCILLATOR CIRCUITS

10-1. Sine waves are produced most commonly by
(a) resonant-element oscillators
(b) multivibrators
(c) relaxation oscillators
(d) all the above

10-2. The sawtooth waveform is used commonly to
(a) energize bridge circuits
(b) acts as a radio-frequency carrier
(c) test circuits
(d) sweep cathode-ray-tube spots

10-3. An oscillating system that uses a resonant device differs from one that uses no resonant device in that the former
(a) oscillates sinoidally
(b) requires amplification
(c) requires less feedback
(d) has all the above characteristics

10-4. In oscillators of any type, it is necessary that the feedback signal have proper
(a) phase only
(b) amplitude only
(c) phase and amplitude only
(d) amplitude and shape only

10-5. A resonant device used in oscillators is
(a) the parallel-resonant tank
(b) the piezoelectric crystal
(c) the tuning fork
(d) any of the above

10-6. The most common type bias used in oscillators is

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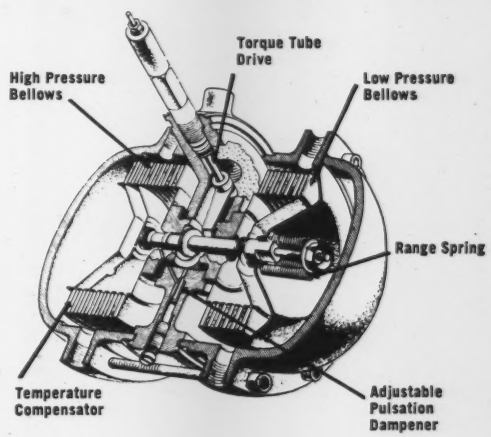

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(a) cathode bias
(b) grid-leak bias
(c) B battery
(d) C battery

10-7. The Hartley oscillator differs from the tickler-coil oscillator in that the former uses
(a) inductive feedback
(b) one tapped coil
(c) a resonant tank
(d) all the above

10-8. The Colpitts oscillator differs from the Hartley oscillator in that the former uses
(a) inductive feedback
(b) a resonant tank
(c) one tapped coil in the resonant tank
(d) one coil and a capacitor voltage divider

10-9. The feedback in the tuned-plate tuned-grid oscillator occurs through
(a) inductive feedback
(b) an R-C phase-shift network
(c) interelectrode capacitance
(d) an external capacitor from plate to grid

10-10. The feedback signal from the plate of a tuned-plate tuned-grid oscillator is in phase with the grid signal because
(a) the plate signal is in phase with the grid signal
(b) the feedback is inductive
(c) there is 90-degree phase change across the feedback capacitance
(d) there is 180-degree phase change across the feedback capacitance

10-11. The ultraudion oscillator differs from the Colpitts oscillator in that the former uses
(a) interelectrode capacitance to effectively tap the coil
(b) a resonant tank between grid and plate
(c) grid-leak bias
(d) a radio-frequency choke to keep r-f. oscillation from the B supply

10-12. The advantage of an electron-coupled oscillator is
(a) frequency stability with load changes
(b) frequency stability with supply variations
(c) use as a frequency multiplier
(d) all the above

10-13. The piezoelectric crystal differs from a parallel-resonant L-C tank in that the former is
(a) an electromechanical resonant element
(b) less affected by temperature changes
(c) more difficult to adjust in frequency
(d) all the above

10-14. Crystal frequencies range from
(a) low audio to high audio frequencies
(b) low audio to ultrasonic frequencies
(c) ultrasonic frequencies to about 100 Mc.
(d) ultrasonic to UHF frequencies

10-15. The tuning-fork oscillator differs from the crystal-controlled oscillator in that the former is
(a) a stable electromechanical oscillator
(b) used at audio frequencies
(c) tunable over a wide band
(d) characterized by good sinoidal waveform

10-16. The magnetostriction oscillator is used mainly to produce
(a) low-power r-f. oscillation
(b) high-power ultrasonic vibrations
(c) high-power UHF oscillation
(d) low-power audio oscillation

10-17. The negative-resistance characteristic of a dynatron oscillator results from
(a) secondary emission in a tetrode
(b) feedback from plate to grid
(c) a negative suppressor potential
(d) an R-C phase-shift network

10-18. The transitron differs from the dynatron in that the former
(a) has higher stability
(b) uses a pentode
(c) does not depend on secondary emission
(d) has all the above characteristics

10-19. Resistance-capacitance oscillators are particularly useful at
(a) audio frequencies
(b) low radio frequencies
(c) UHF frequencies
(d) all the above frequencies

10-20. The Wien-bridge oscillator differs from the phase-shift oscillator in that the former uses
(a) a 3-stage R-C feedback network
(b) a frequency-selective bridge
(c) one amplifier stage
(d) all the above

10-21. The neon sawtooth generator is
(a) a relaxation oscillator
(b) an R-C phase-shift oscillator
(c) a UHF oscillator
(d) a multivibrator

10-22. The thyratron sawtooth generator differs from the neon sawtooth generator in that the former
(a) is a relaxation oscillator
(b) provides control of frequency
(c) provides control of amplitude
(d) uses a gas tube as a switch

10-23. The term "synchronizing" an oscillator refers to
(a) locking to the same frequency as an external signal
(b) reducing temperature sensitivity
(c) use of crystal control of frequency
(d) adjustment of frequency over a wide band

10-24. The multivibrator is primarily a
(a) phase-shift square-wave oscillator
(b) relaxation-type sine-wave oscillator
(c) relaxation-type sawtooth generator
(d) relaxation-type square-wave generator

10-25. The Eccles-Jordan flip-flop circuit differs from the basic multivibrator in that the former
(a) operates only when triggered
(b) has d-c. coupling from plates to grids
(c) has two conditions of equilibrium
(d) has all the above characteristics

10-26. A basic use of the Eccles-Jordan flip-flop circuit is in
(a) production of sine waves
(b) production of sawtooth waves
(c) production of square waves
(d) scale-of-two counting

10-27. The term "heterodyning" refers to
(a) the mixing of sine waves of different frequencies
(b) the production of sum and difference frequencies
(c) the production of beat frequencies
(d) all the above

10-28. Which of the following

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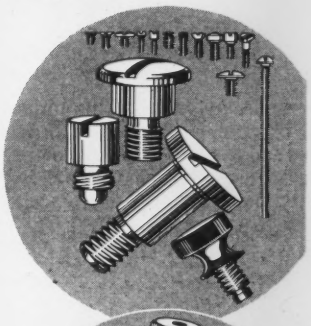

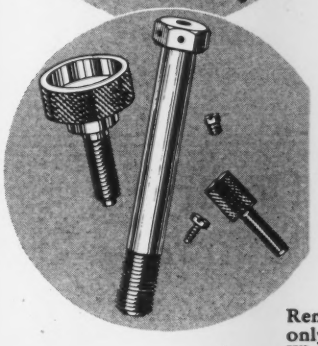

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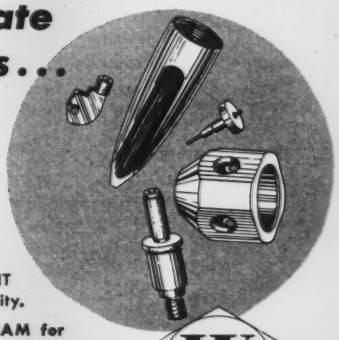

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can be used as a mixer for heterodyning signals?
(a) Any linear amplifier.
(b) Any sine-wave oscillator.
(c) Any square-wave generator.
(d) Any nonlinear device.

10-29. A shock-excited oscillator produces a
(a) continuous sine wave
(b) damped sine wave
(c) continuous sawtooth wave
(d) damped sawtooth wave

10-30. The most common type of resonant element used in oscillators operating between 100 and 1000 Mc. is the
(a) phase-shift network
(b) inductor and capacitor in parallel
(c) butterfly tank
(d) cavity resonator

10-31. The most common resonant element used in oscillators operating above 1000 Mc. is the
(a) phase-shift network
(b) inductor and capacitor in parallel
(c) butterfly tank
(d) cavity resonator

10-32. Oscillation is induced in cavity resonators by
(a) passage of electrons through or near the cavity
(b) collision between electrons and the cavity walls
(c) feedback from plate to grid
(d) feedback from plate to cathode

10-33. The purpose of the buncher cavity in the Klystron is to provide
(a) r-f. output
(b) bunches of electrons
(c) feedback to the catcher cavity
(d) all the above

10-34. The purpose of the catcher cavity in the Klystron is to provide
(a) r-f. output
(b) feedback to the buncher cavity
(c) a resonant cavity
(d) all the above

10-35. The difference between a reflex Klystron and a conventional Klystron is that the former has
(a) a buncher cavity only
(b) a catcher cavity only
(c) one cavity only
(d) one drift space only

10-36. The difference between a magnetron and a Klystron is that the former
(a) is a velocity-modulated tube
(b) uses resonant cavities
(c) is a microwave-frequency oscillator
(d) uses a magnetic field to direct electrons

10-37. The local oscillator in microwave receivers usually is a
(a) Hartley
(b) Colpitts
(c) Klystron
(d) magnetron

10-38. The source of high-power UHF radar pulses usually is the
(a) ultraudion
(b) dynatron
(c) Klystron
(d) magnetron

A-C. MEASUREMENTS

Continued from page 757

way the instrument should be tested occasionally to determine corrections for the scale at the cardinal points. However, these sources of error can be effectively eliminated if a thermocouple ammeter or voltmeter is used as a transfer instrument. The transfer principle implies that the instrument must have the same response on a.c. as on d.c.

Fig. 1 illustrates a method for connecting a voltmeter for a transfer test. An ammeter can be connected in a similar way. The pointer of the voltmeter deflects in response to the alternating voltage (A.V.) to be measured. The dpdt switch is immediately thrown to the direct voltage (D.V.) position and the voltage box controls are adjusted until the same pointer deflection is obtained. This direct voltage is measured with a potentiometer and voltbox arrangement. A second measurement is made with the polarity at the voltmeter reversed. The mean of the values of reversed direct voltage gives the value of alternating voltage in question. This method provides an accurate means of measuring alternating voltage because it eliminates the temperature error and any drifts in the millivoltmeter or thermocouple. The over-all accuracy depends on the extent to which other sources of error have been minimized.

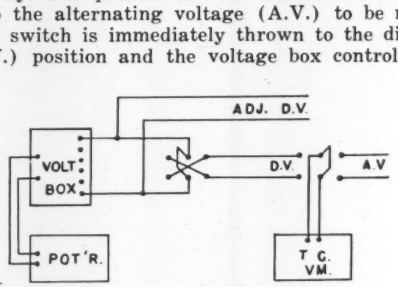

Fig. 1.

One limitation of this method is the ability of the observer to make repeat setting of the pointer. If greater accuracy is desired in repeating a given deflection, the instrument can be placed under a low-power microscope that has a reticule in its optical system. In this procedure the pointer

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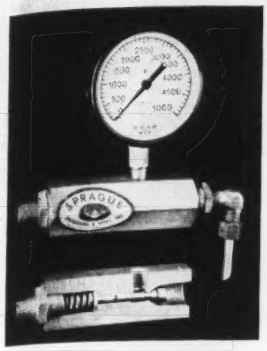

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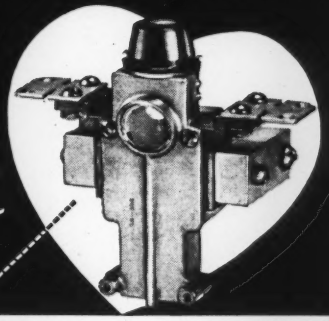

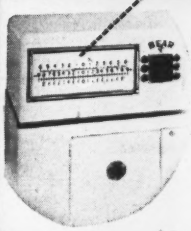

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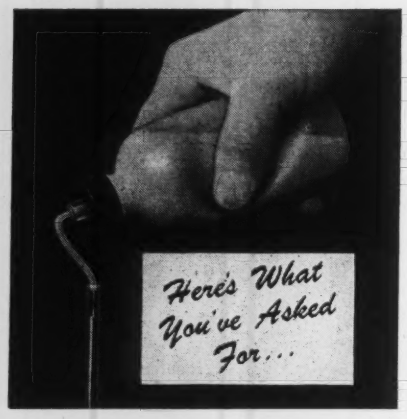

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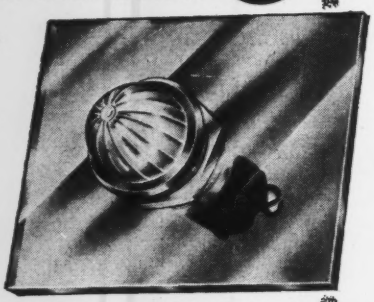

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is brought in focus and the reticule scale substituted for the instrument scale.

Certain precautions must be taken in the care and use of a thermocouple instrument. (See reference 4.) Ordinarily the heater of the thermoelement can withstand only small overloads. As each element has certain individual characteristics, it may be difficult to find a suitable replacement when one has been damaged or "burned out." In such instances it may be advisable to return the instrument to the manufacturer for the necessary adjustment and replacement.

REFERENCES

(1) Hermach, Francis L., "Thermal Converters as AC-DC Transfer Standards for Current and Voltage Measurements at Audio Frequencies," NBS *Journal of Research*, Vol. 48, February 1952.

(2) Miller, John H., "Compensation of A-C Instruments for Variations in Frequency," *Electrical Engineering*, Vol. 70, June 1951, pages 494-497.

(3) Richardson, S. C., "Performance of Conventional Indicating Instruments at Frequencies up to 3000 Cycles," *General Electric Review*, Vol. 46, October 1943, pages 565-569.

(4) Weaver, Frank D., "Notes on the Care and Use of Electrical Instruments," *Instruments*, Vol. 23, No. 12, December 1950, pages 1236-1239.

(5) Westinghouse Electric Corporation, "Electrical Instruments, The Eyes and Ears of Industry," Westinghouse Electric Corp., Meter Div., Newark, N. J., pages 50-52.

VALVE-SIZING METHODS

Continued from page 756

plotted from data taken on the same body assembly that was used in the test plotted in Fig. 10, except air was used for the test medium instead of water. Note that the "flow closes" curve does not break as quickly or as sharply, and that the "flow opens" capacity is only about 65 percent greater than the "flow closes" capacity.

The foregoing tests indicate that angle bodies should be installed so that the flow tends to open the inner valve if the normally expected capacities are to be realized. Installation in this manner, of course, obviates the advantage of less coking and erosion in the angle body.

However, the picture is not quite as black as it seems because field experience indicates that streamlined angle valves handling flashing liquids (such as steam condensate and hot hydrocarbons) at least approach the normally expected capacities of single-seated valves, although we have no actual laboratory test data to substantiate this.

CONCLUSION

Control-valve sizing, in all its aspects, definitely has not been reduced to an exact mathematical science. The present practice of using valve coefficients determined by low-pressure water tests for determining gas and steam capacities can lead to serious error. More work needs to be done in determining capacity corrections for viscosity and (although not discussed in this article) for supercompressibility at high pressures. Also, at the present time there is no scientific basis for sizing valves handling fluids that flash with pressure drop. A program of correlating all existing data, and encouraging further research in the many problems of control-valve sizing would render a much-needed service to the industry. Such a program should be considered by an authoritative national society.

ERRATUM

An error appeared in the advertisement of the Liston-Becker Instrument Co., of Stamford, Conn., in our May issue, which they have asked us to correct. The range of sensitivity of their Infrared Gas Analyzer to almost any heteroatomic gas covers concentrations of *0.05%* to 100%, NOT 0.5% as given.

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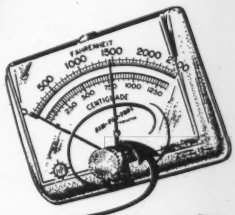

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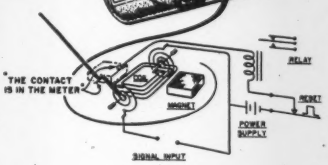

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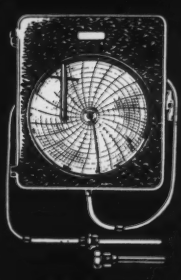

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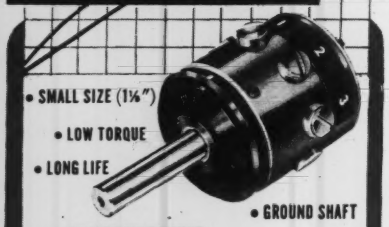

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BISMUTH THERMOCOUPLES

Continued from page 762

Over-all accuracy, particularly with items of low thermal mass, is improved because the bismuth thermocouple robs the contact point of heat only 1/240th as fast as copper.

Practical Factors

The use of bismuth for thermocouples requires several notes concerning the junction and materials. In making the junction, do not use any solder of any kind. Solder introduces foreign elements and makes the junction unstable metallurgically and electrically. Do not use a flux for the same reasons. For mechanical support, wind alloy "B" around the ductile bismuth and, using an absolutely clean soldering iron at 480 deg. F., *fuse* alloy "B" to the ductile bismuth. Alloy "B" fuses at 420 deg. F. and ductile bismuth at 520 deg. F. The bismuth should not be melted because then it reverts to its brittle state and weakens the joint. Therefore, *be sure* you melt alloy "B" and not the bismuth. They fuse perfectly. If the wire is insulated it may be cleaned by dipping in acetone and wiping clean.

The problem of making satisfactory junctions with the bismuth thermocouple wires indicates the use of a mechanical connection at the cold junction. It is impossible to fuse the bismuth to copper for an ice-bath reference, but the wires can be held together mechanically and submerged in the ice bath. It may be preferable to use a potentiometer with automatic cold-junction compensation, or arithmetically correct the standard potentiometer indication for cold-junction temperature. This latter method was employed in the experimental investigation undertaken by the author.

Although Fitzpatrick bismuth wire is ductile, flexing of any amount causes failure of the wire. In fine-wire form it can be wound on its own diameter and can make rather sharp bends at ordinary room temperatures. The wire is not ductile in the same sense as copper and other ductile metals, but it is sufficiently ductile to be used for permanent installations. It will not withstand continuous vibration and should be held by some thermo-setting plastic for rigidity. The bismuth-alloy wire "B" appears much more ductile than the pure bismuth wire.

The use of a bismuth thermocouple or thermopile for power generation involves several questions, including the internal resistance of the thermocouple and the available hot-junction temperature. Bismuth can be used for measuring high temperatures by using a heat-conducting prod to the bismuth so as to limit the temperature. This procedure eliminates possibility of the thermocouple oxidizing by high-temperature gases of corrosive materials. If the prod has a 12 to 1 thermal drop between the high-temperature and low-temperature end, 3000 deg. F. at the prod produces 250 deg. F. at the couple. With such high temperatures it might be more satisfactory to use an iron-constantan or chromel-alumel couple.

The advantage of bismuth is its high output at low temperatures. This is seen in Table I.

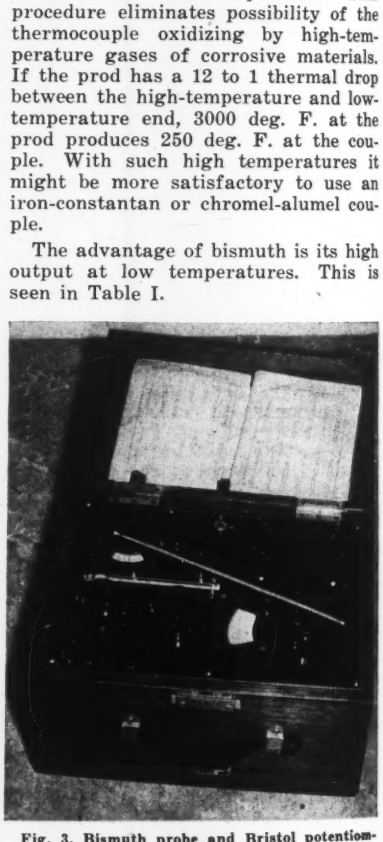

Fig. 3. Bismuth probe and Bristol potentiometer. Tip of sensitive bismuth couple extends from end of insulating tube.

TABLE I—COMPARISONS OF THERMOCOUPLE FEATURES

Couple	*mv. at 200 deg. F**	*Dual TC ohms/ft. (#18)*	*K*
Alloy "B" & Bismuth	6.85	0.98	7.0
Fe-Const	4.92	0.235	21.0
Cu-Const	3.97	0.190	20.9

*32 deg. F. reference

It is standard engineering knowledge that when the impedance (Z_0) of a generator matches the impedance (Z_1) of the load, maximum transfer of power from the generator into the load occurs. Thus both the voltage and current output of a generator or thermocouple must be considered to determine which is most satisfactory as a power source. For a given wire size, the ability of a thermocouple to operate a relay or other power device, at a given hot-cold junction temperature, is the ratio of its internal resistance to its output potential. This quality factor K is $mv./Z_0$ or $mv./R$.

As K is a measure of current output, a large K means greater power output. Thus it is seen that the bismuth couple is not ideal for power generation. However, the best available couple for high temperature can be the one with poor K. For example, alloy "B" and bismuth at 200 deg. F. puts out 6.85 mv., whereas iron-constantan at 1600 deg. F. puts out 50 mv. Thus, even if the K factor of the iron-constantan were considerably less than the bismuth, it would still put out more power at higher hot-junction temperatures. The K factor is approximately correct only for a given wire size and temperature and should not be compared on any other basis. This factor varies widely when wire size is changed.

It is interesting to note that both germanium and silicon vs. lead give approximately 5 to 10 times the output available from bismuth. However, germanium is not available in ductile wire, and silicon has inherently high resistance. Further the K factor for both is low, negating their use for thermoelectric power generation. Silicon-carbide vs. carbon couples are not applicable to the installation and temperature ranges covered by bismuth.

The use of bismuth couples and thermopiles for temperatures from below zero to 250 deg. F. is undoubtedly indicated for temperature instrumentation.

TABLE II—DUCTILE BISMUTH WIRE

Size A.W.G. Approx.	*Dia. Approx.*	*Ohms Resistance Per Ft.*
18	0.039	0.49
23	0.0226	1.45
29	0.0113	5.95
34	0.0062	20.0
36	0.005	30.0
37	0.0045	37.0
39	0.0035	62.0

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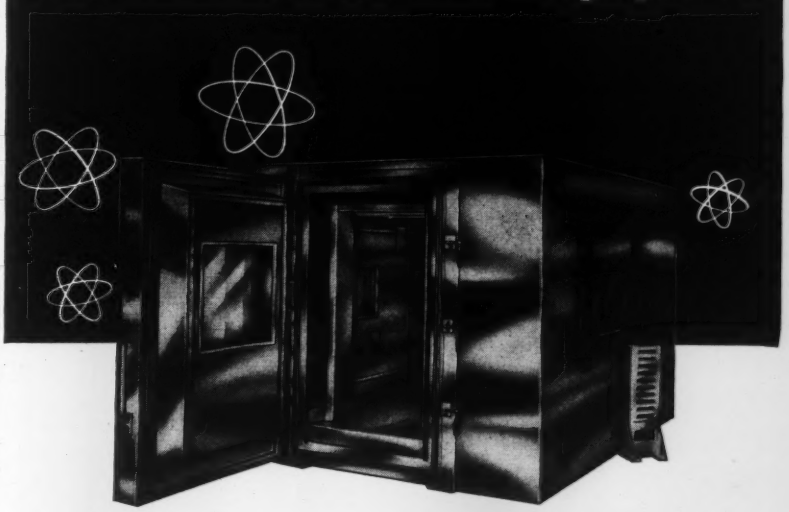

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INSTRUMENTS ON THE MARCH

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Analog-to-digital Converter

WASHINGTON, D. C.—A new electronic device, the "Anodige," has been developed recently at the National Bureau of Standards, according to Technical Report 1657. The device, developed by M. L. Kuder, translates voltage or other electrical quantities into discrete digits. Digital indication offers important advantages over analog indication in speed of response, accuracy, and utility of coded-pulse output.

The heart of the circuit is a capacitor that is charged in equal increments until the integrated capacitor voltage (marked E_K in Fig. 2) reaches the unknown voltage. In one model, the measurement operation is automatically repeated 400 times a second. At the beginning of each measurement, a 400-cps. programming oscillator turns on a 100-kc. master oscillator through an electronic switch. The capacitor, or analog integrator, starts to build up d-c. voltage at the rate of one 0.1-volt step per master-oscillator cycle. The voltage across the integrating capacitor is fed to one side of a balance detector; the unknown voltage is applied to the other side. The balance detector transmits a stop signal to the electronic switch when the two voltages are equal.

Three electronic decade counters count the number of increments. The total count is indicated on 3 rows of lights and is recorded on electrosensitive recording paper. With 0.1-volt increments, the full-scale reading is 100 volts. Units with increased sensitivity are under development.

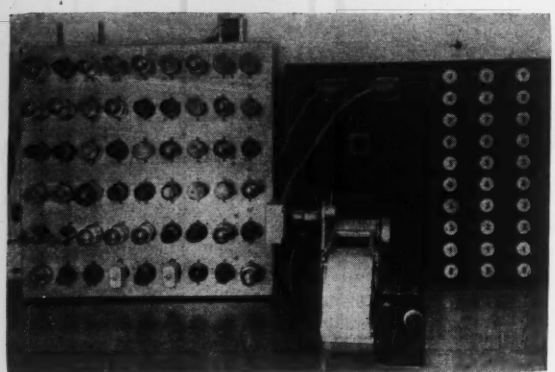


Fig. 1. Analog-to-digital converter, showing circuit chassis, indicator lights, and electrosensitive-paper recorder.

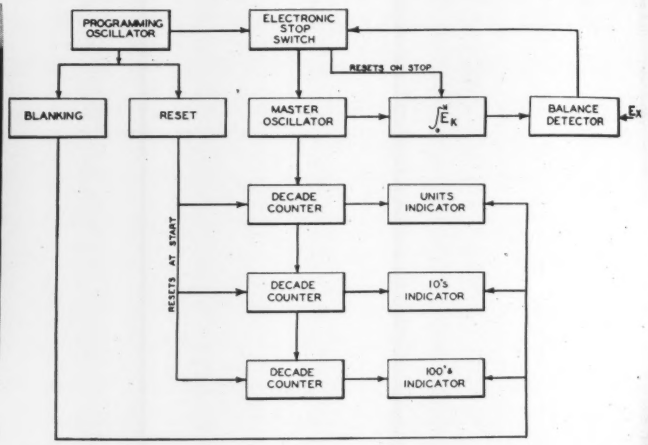


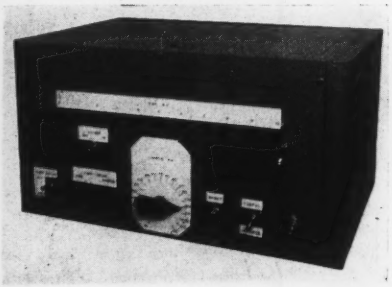
Fig. 2. Block diagram of circuit.

Peak-reading Kilovoltmeter

WASHINGTON, D. C.—An instrument to measure the voltages associated with X-ray tubes has been developed by R. E. Brueckmann of the National Bureau of Standards, according to Technical Report 1652. The measuring circuit consists of eleven 2D21 thyratrons, each having a neon glow tube in its plate circuit.

The thyratrons are biased in 1-volt increments by potentiometer voltage dividers. A 22-position selector switch (coarse kv.) adds from 30 to 125 volts in 5-volt steps to the bias on each tube. Thus the thyratrons can be biased from 31 to 135 volts. As the input is a 1000 to 1 voltage divider, a voltage between 30,000 and 135,000 volts fires all tubes below the critical bias. The reading is the sum of the setting on the coarse-kv. switch and the number indicated by the last activated neon lamp. The switch must be preset within 10 kv. of the reading, and the reading is within 1 kv.

The neon lamps remain lighted until reset. A reversing switch between the



voltage divider and the coarse-kv. selector switch permits measurement of either the positive or negative peaks of the voltage applied to the potential divider and, hence, either the useful or inverse kilovoltage. A calibrating circuit is included in the instrument for setting the bias voltages of the eleven thyratrons. A time-delay circuit, incorporated to prevent recording of the starting surge, includes two thyratrons and two relays.

Humidity Safeguard

MINNEAPOLIS, Minn.—A new electronic humidity indicator and portable meter has been developed by Minneapolis-Honeywell to help the Armed Forces safeguard packaged military equipment during storage. A tiny, highly accurate sensing element (left) is placed inside of sealed packages, with electrical wires running to out-

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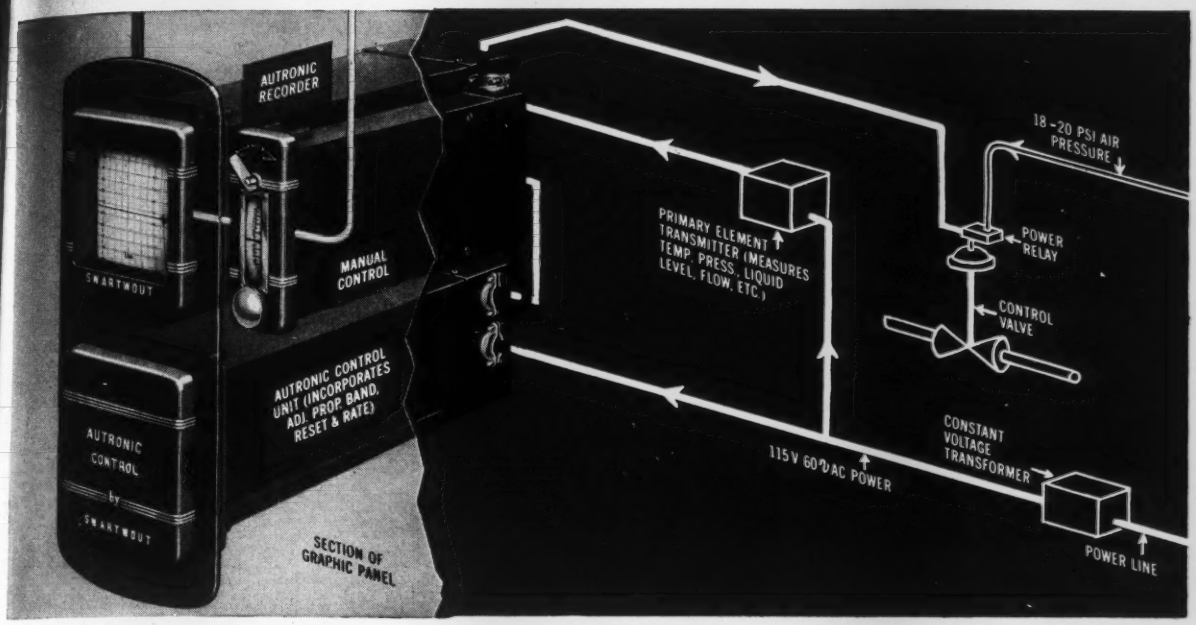
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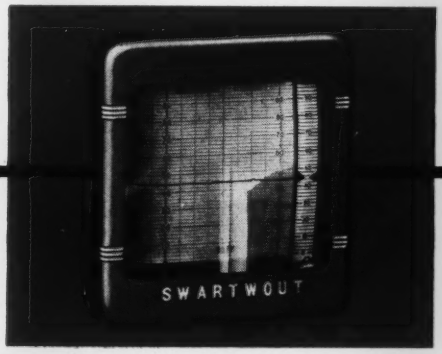

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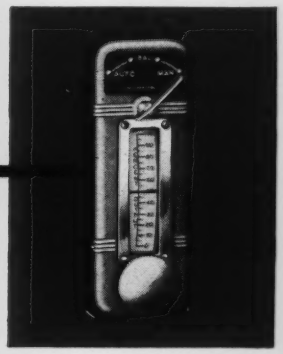

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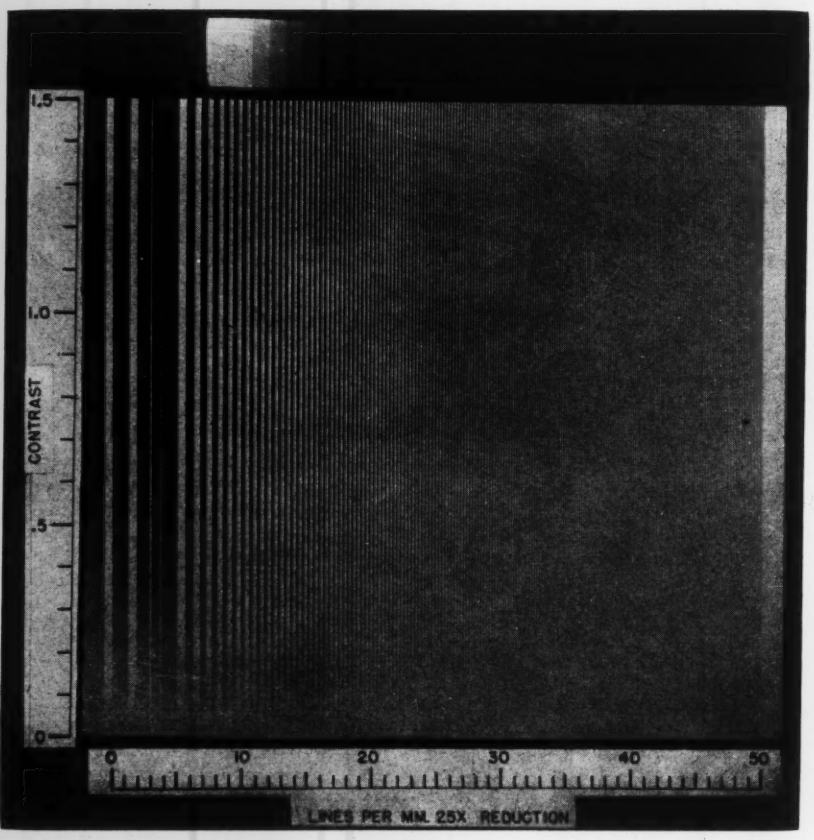
side connections. The portable meter (right), when plugged into an outside connection, shows whether moisture content inside the package is great enough to cause rust and corrosion.

Resolving-power Test Chart

WASHINGTON, D. C.—The resolving power of photographic lenses now can be more effectively measured and studied by means of a variable-contrast test chart recently developed at the National Bureau of Standards, according to Technical Report 1622. The new chart enables the user to obtain in a single photograph a complete record of the resolution characteristics of a lens for any value of target contrast in the range from 0.0 to 1.5. The test chart measures the resolving power of a lens and shows the variation of resolving power with contrast.

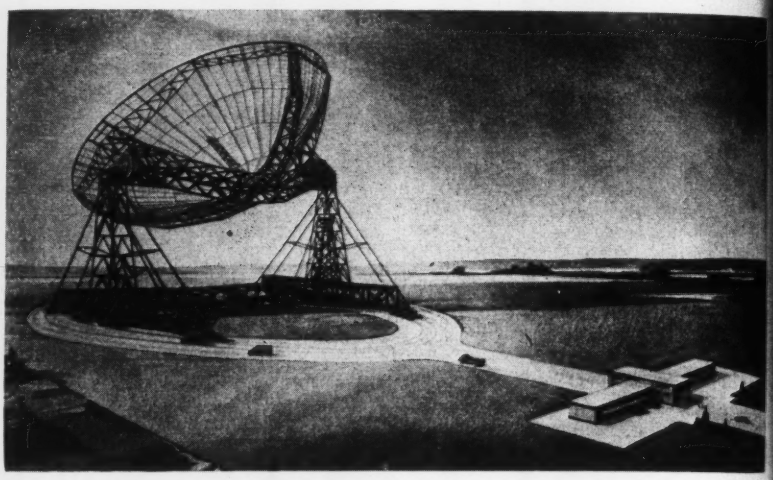
The test chart consists of a series of long parallel lines so arranged that the widths of successive lines and of the spaces separating them progressively decrease. At the same time, the transmittance of the lines and spaces varies from end to end in such a way that the contrast at any place in the chart is a linear function of the distance from one edge of the chart. The first four white lines are the widest (repeated twice), the average, and the smallest of the lines of the chart which follows. The chart is being recommended as an International Standard.



Radio Telescope

MANCHESTER, England.—A giant radio telescope weighing 1,270 tons is to be built in Britain to map unexplored regions of the universe. It will enable scientists to pick up signals from invisible stars sent out hundreds of millions of years ago from outer space.

The paraboloid antenna can rotate on a platform mounted on two 185-ft. elevating racks. Total cost is expected to approach $940,800, half of which will be paid by the Nuffield Foundation and half by the British Government. The work is an outgrowth of the discovery in 1931 by the U. S. scientist Jansky that stars emit radio waves that can be received on earth. Construction will be completed in less than four years.



Vibration Instrumentation

The Applied Mechanics Division of the American Society of Mechanical Engineers announces a Shock and Vibration Instrumentation Symposium to be held during its summer meeting at Pennsylvania State College, State College, Pennsylvania, June 19-21, 1952.

The program includes papers in the following categories: (1) Survey and historical; (2) One-degree-of-freedom instruments; (3) Sources of error and secondary effects; (4) Peak reading gages; (5) Calibration; (6) Applications. The symposium will close with a general discussion intended to bring out the difficult and intriguing problems which are in urgent need of solution in the instrumentation field and thus to stimulate further development.

Automatic Kiln Control

EAST CAMBRIDGE, Mass.—The exacting wood-drying requirements in the making of burial cases are met by the National Casket Company plant at East Cambridge by "Foxboro" automatic control. Capacity of the compartment-type kiln is 60,000 board feet per load. Oak, maple, and willow are among the woods regularly dried. The kiln is held to precise drying schedules by a multi-zone temperature recorder-controller with dual dry bulbs and duplex wet-

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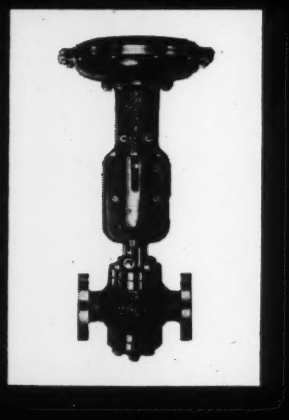

The isolating valve in the stem lubricator of the Honeywell Series 700 Valve affords maximum safety against leakage when replenishing stem lubricant . . . tight-fitting conical plug and machined seat assure leakless shut-off . . . pinned bonnet prevents accidental removal. The Honeywell Series 700 wide band proportional valve comes in a full range of styles and sizes . . . has *all* the features you look for in a fine valve. Write today for your copy of Bulletin 700-2.

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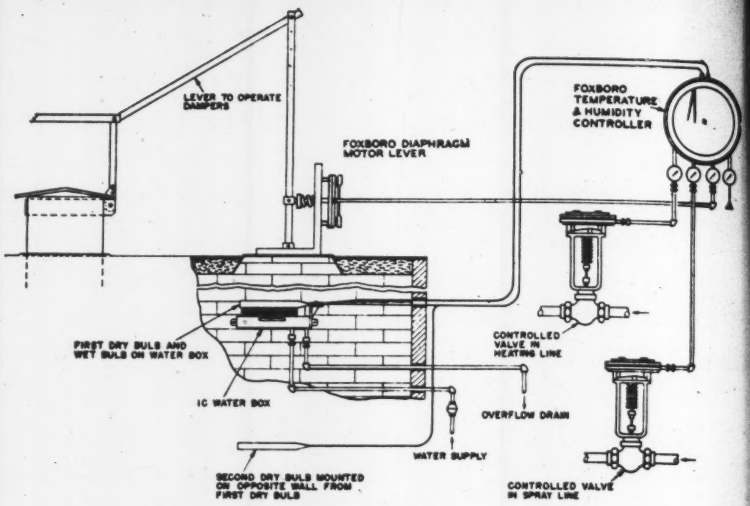
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WATER SUPPLY
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CONTROLLED VALVE IN SPRAY LINE

bulb control. Humidity control for the entire kiln is maintained by the wet-bulb system, and the duplex feature insures that the dampers and the steam spray valve cannot be opened at the same time.

Moisture Measurement

NIAGARA FALLS, N. Y.—As coated abrasive rolls out of drying room at the Carborundum Company, Coated Products Division, Niagara Falls, an operator uses "TAG Midget Moisture Meter" to be sure product has proper degree of moisture content. Moisture determination improves quality and prevents losses due to (1) mold and paper delamination from excessive moisture or (2) bond failure from lack of sufficient moisture.

INSTRUMENT EVENTS CALENDAR

June 19-21
ASME Applied Mechanics Division Symposium on Shock and Vibration Instrumentation, Pennsylvania State College, State College, Pa. For information write W. D. Kroll, Physicist, National Bureau of Standards, Washington 25, D.C.

June 23-27
ASTM 50th Anniversary Meeting and 10th Exhibit of Testing Apparatus and Laboratory Supplies, Hotel Statler, New York, N. Y. For information write Robert J. Painter, Asst. Sec., American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

July 28-Aug. 1
Gordon Research Conference on Instrumentation sponsored by the American Association for the Advancement of Science, Colby Junior College, New London, N. H. For information write W. George Parks, Director, Dep't of Chemistry, University of Rhode Island, Kingston, R. I.

Sept. 4-13
International Society of Photogrammetry, Shoreham Hotel, Washington D. C. For information write L. Ray Smart, U. S. Geological Survey, Trimetrogon Section, Washington 25, D. C.

Sept. 8-12
Instrument Society of America.
Seventh National Instrument Conference and Exhibit.
Public Auditorium, Cleveland, Ohio.

Sept. 22-30
Third Instruments and Measurements Conference and Exhibition, Stockholm, Sweden. For information write Mr. Yngve Axner, Kungl. Tekniska Hogspolan, Stockholm 70.

Sept. 29-Oct. 1
Eighth National Electronics Conference and Exhibition.
Sherman Hotel, Chicago.
For information write Karl Kramer, Ex. Sec., 852 E. 83rd St., Chicago 19.

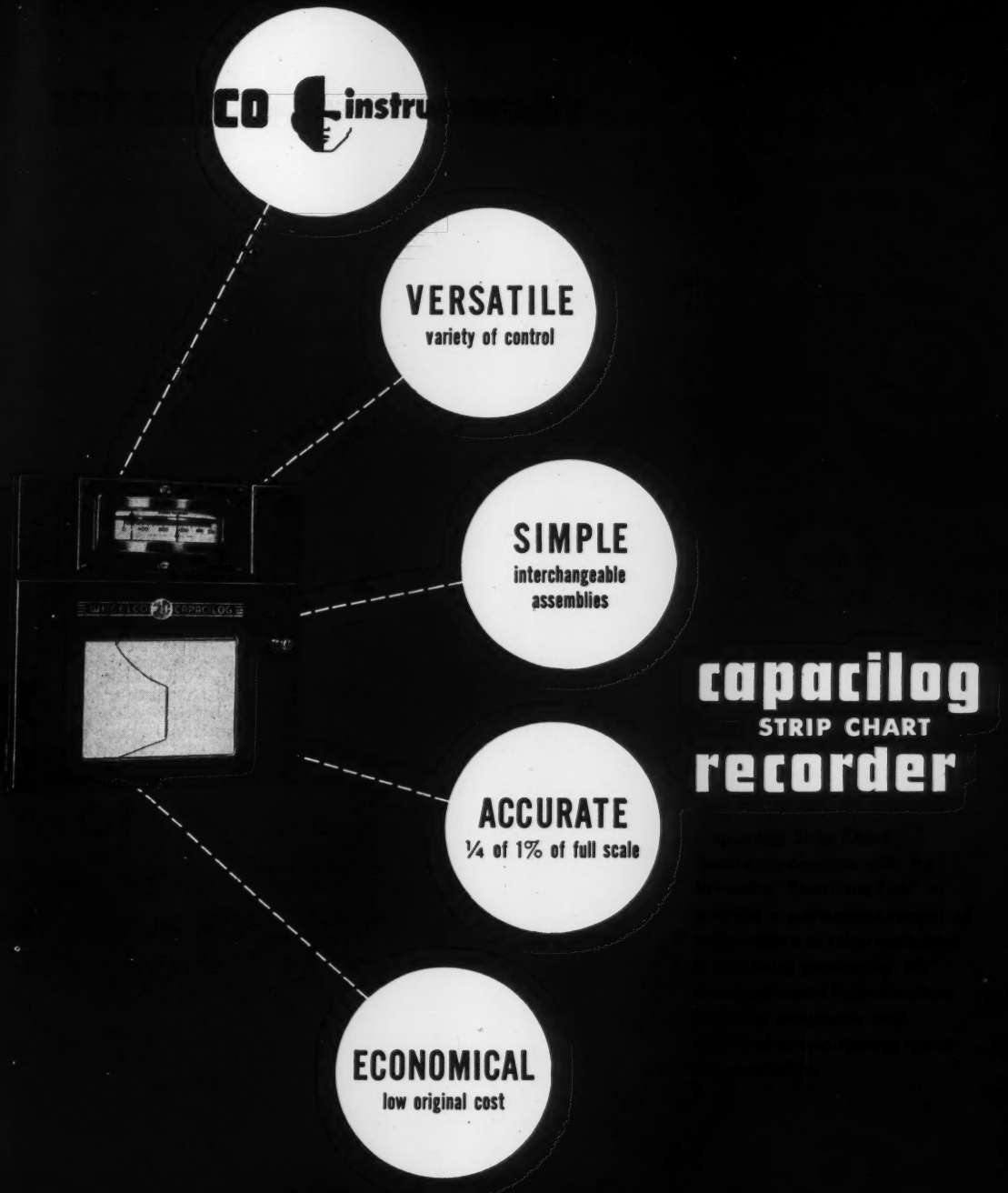
October
Scientific Apparatus Makers Association.
Midyear Meeting of Recorder-Controller Section.
Seaview Country Club, Absecon, N. J.

Nov. 5-9
Scientific Apparatus Makers Association.
Midyear Meeting of Industrial Instrument, Laboratory Apparatus, Laboratory Equipment, Optical, Aeronautical, and Military Instruments Sections.
The Homestead, Hot Springs, Virginia.

Nov. 17-18
AIEE Technical Conference on Electrically-operated Recording and Controlling Instruments.
Benjamin Franklin Hotel, Philadelphia, Pa. For information write G. L. Broomell, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia 44.

Nov. 20-22
Instrument Maintenance Short Course sponsored by Southern California Meter Association at Long Beach, Calif.

Dec. 3-4
Annual Meeting and Exhibits, Society for Experimental Stress Analysis, Hotel McAlpine, New York City. For information write W. M. Murray, Sec.-Treas., P.O. Box 168, Cambridge 39, Mass.



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Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

Pressure

U-494 **Dynamic Pressure Indicator.** 7-page bulletin illustrates and describes new "Model ST-12 Electronic Pickup Indicator" having very high frequency response. Includes construction and specifications.—Rutishauser Corp., 490 So. Fair Oaks Ave., Pasadena 1, Calif.

U-495 **Manometer Calibration.** 2-page Data Sheet U-51 gives standard calibrations for new "Type-B" straight-tube U-tube manometers for water, mercury, red No. 1, or red No. 2 indicating fluids.—Uehling Instrument Co., Paterson, N. J.

U-496 **Miniature Pressure Transducer** 2-page reprint contains article on use of miniature flush-mounted pressure transducer in aviation research.—Statham Laboratories, Inc., 12401 W. Oylmpic Blvd., Los Angeles 64, Calif.

Temperature

U-497 **Temperature Control.** 8-page illustrated Folder ND47-33C(2)90-252 covers features and typical industrial applications of maker's "Electromax" temperature controller.—Leeds & Northrup Co., 4907 Stenton Ave., Phila. 44, Penna.

U-498 **Temperature Control.** 4-page Bulletin G-2, 4-page Bulletin CMR-79, and 2-page Bulletin SP-78, describe and give catalog data on "Sim-ply-trol" indicating-controlling pyrometers.—Assembly Products, Inc., Main at Bell Sts., Chagrin Falls 3, Ohio.

U-499 **Temperature Control.** 2-page Bulletin 15a introduces a new precision controller using a resistance thermometer, bridge and electronic amplifier. Includes features.—Technical Equipment Co., 4348 San Pablo Ave., Emeryville 8, Calif.

U-500 **Pyrometers.** 12-page illustrated Brochure GEC-713A covers principles, features, and applications of maker's line of indicating and controlling pyrometers. Also new line of resistance thermometers.—General Electric Co., Schenectady, N. Y.

U-501 **Thermometers.** 4-page illustrated Catalog A-52 describes maker's large line of mercury-in-glass and petroleum-distillate-in-glass thermometers. Includes specifications and prices.—Brooklyn Thermometer Co., Springfield Gardens, L. I., N. Y.

U-502 **Resistors for Temperature Measurement and Control.** 8-page Bulletin No. 13 describes in detail maker's line of "NTC" (negative temperature coefficient) resistors; illustrates and catalogs various standard production units; contains graphs of characteristics; concludes with Questions & Answers.—Keystone Carbon Co., St. Marys, Penna.

U-503 **Thermal-sensitive Resistors.** 30-page Catalog TH-5 illustrates and describes maker's line of rod, disk, and washer-type "Thermistors." Includes physical and operating characteristics; also typical applications in temperature measurement, vacuum gages, time delay, flow metering, switching, etc.—Carboloy Dept., General Electric Co., Detroit 32, Mich.

U-504 **Thermocouple Glands.** 4-page Bulletin 951 describes a new type of gland for sealing bare TC wires; gives detailed specifications and instructions.—Conax Corp., 4515 Main St., Buffalo 21, N. Y.

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U-505. **Thermowells.** 20-page illustrated catalog describes maker's large line of thermometer and thermocouple wells. Includes features and specifications.—Karn Chemical Equipment Co., 518 Dickson Ave., Pittsburgh 2, Penna.

Temperature Cabinets

U-506 **Low-temperature Cabinets.** 4-page bulletin entitled "Industrial Cold" describes eight industrial models and four laboratory models of cabinets for producing temperatures as low as minus 100 deg. F.—Industrial Cold Div., American Injector Co., 1000 E. McNichols Rd., Detroit 3, Mich.

U-507 **Low-temperature Cabinets.** 8-page Bulletin 101 and 2-page brochure illustrate and describe maker's low-temperature test cabinets. Includes specifications and applications.—Sub-Zero Products Div., Deepfreeze Distributing Corp., 3932 Reading Rd., Cincinnati 29, Ohio.

U-508 **Temperature Cabinets.** Four 1-page bulletins describe a series of cabinets for testing a variety of products under controlled high and low temperatures and controlled relative humidity.—Food Technology Inc., 5903 Northwest Highway, Chicago 31, Ill.

Flow

U-509 **Rotameters.** 4-page Vol. 4 No. 1 issue of "SK Engineering News" features articles on "Rotameters," gas scrubbers, multi-jet condensers, and others.—Schutte and Koerting Co., Cornwells Heights, Bucks Co., Pa.

U-510 **Positive Metering.** 20-page illustrated brochure Form 566-7 describes maker's large line of positive meters, registers, and accessories for industrial fluids. Includes new "Type S Auto-Stop" meters and selection data.—Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.

Level and Combustion

U-511 **Level Control and Safety Devices.** 24-page Bulletin SC-2 covers features, applications, and selection data for maker's boiler-water feeders, low-water fuel cut-offs, pressure-relief valves, flow switches, and other boiler-house instruments.—McDonnell & Miller, Inc., 3500 N. Spaulding Ave., Chicago 18, Ill.

U-512 **Level Control.** 40-page illustrated brochure covers maker's large line of floatless liquid-level and industrial contactors, starters, and controls. Includes history, principles, operation, and applications.—B/W Controller Corp., 2200 E. Maple Rd., Birmingham, Mich.

U-513 **Liquid-level Indication.** 4-page "Unit No. 179" (replacing "Unit No. 128") catalogs maker's heated and cooled gages and valves.—Jerguson Gage & Valve Co., 80 Fellsway, Somerville 45, Mass.

U-514 **Well Level Control.** 2-page Application Engineering Data Sheet 831-9 illustrates and describes maker's "Rotax" pump well level control system for water or sewage. Includes specifications and operation.—The Foxboro Co., Foxboro, Mass.

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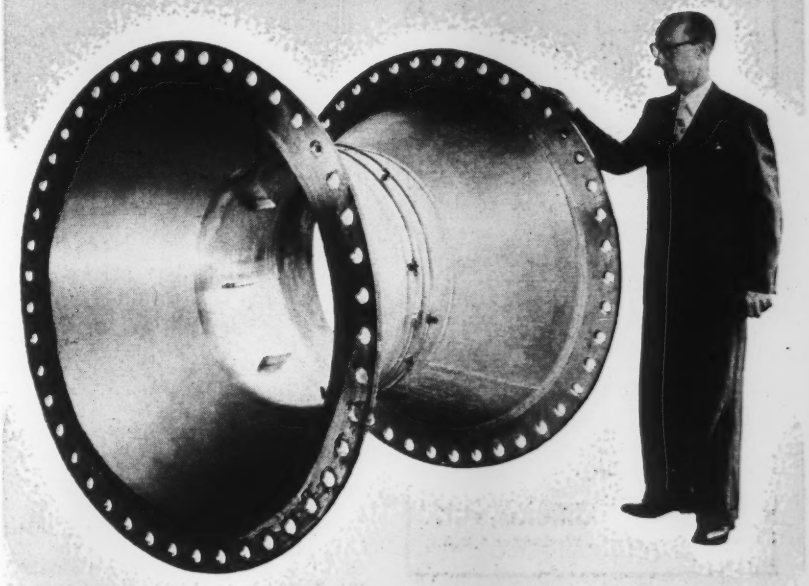

This 48" Foster Type D Flow Tube, of lightweight fabricated steel construction for measuring flow of air in the discharge line of a reactor air system, flanged for 125#, is only 48" in length between flanges and weighs only 1350 lbs. — many feet shorter and several thousand pounds lighter than a conventional venturi.

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Foster Flow Tubes are made for a wide range of services metering the flow of liquids and wet or dry gases. They are available in all commercial pipe sizes, with screwed or flanged connections, bell and spigot, or welding ends, and of any materials required by the service. For further information on Flow Tubes, ask for Bulletin FT-101; and if you would like specific recommendations, please give us processing and installation details of your metering requirements.

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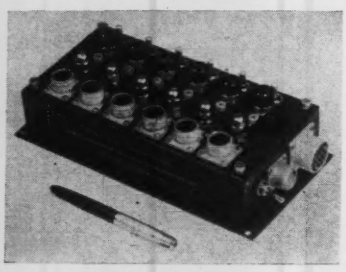

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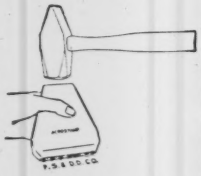

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NEW LITERATURE

U-515 **Smoke Detection.** 4-page Bulletin 521 describes three models of maker's instruments for detecting smoke accidentally introduced into air intake of air-conditioning systems.—Ess Instrument Co., 96 S. Washington Ave., Bergenfield, N. J.

Weighing

U-516 **Scales.** 28-page Condensed Scale Catalog No. 11 covers complete line of modern scales for industrial need. Includes selection data on a thousand scales, including beam indication, tape-drive dial, "Weightograph" projection, and new "Teleprint Electronic Remote Weight Recorder."—The Howe Scale Co., Rutland, Vt.

U-517 **Laboratory Balances.** 4-page Bulletin 3270 illustrates and describes features of new "Shadograph" fast-reading laboratory balances, including specifications.—The Exact Weight Scale Co., Columbus 8, Ohio.

U-518 **Weighing Accessory.** 4-page Form 668 illustrates and describes a new projection type of weight indication which can be attached to any beam scale.—The Howe Scale Co., Rutland, Vt.

Stress Analysis

U-519 **Stress-analysis Instrumentation.** 4-page Bulletin 5 describes "Models BA-2 and BA-12" bridge amplifiers and "Model BS-6" switch balance unit for experimental stress analysis with resistance-type pickups.—Ellis Associates, Box 77, Pelham, N. Y.

Radioactivity

U-520 **Fast-neutron Dosimeter.** 2-page bulletin describes "Model E-1 Raychronix" with response proportional to human-tissue sensitivity for fast neutrons from 0.2 to 10 Mev.—Radioactive Products, Inc., 443 West Congress, Detroit 26, Mich.

Process Controllers

U-521 **Process Control.** 32-page illustrated Bulletin 461-10M-11-51 covers components, features, and operation of maker's "M 40" pneumatic controller. Includes principles, operation, and applications of on-off, proportional, reset, and derivative control actions.—The Foxboro Co., Foxboro, Mass.

U-522 **Process Control.** 28-page Vol. 4 No. 3 issue of "Taylor Technology" features technical articles on drying air continuously, retort control, "Bi-Act Controller," waste-soda measurement, and others.—Taylor Instrument Companies, Rochester 1, N. Y.

U-523 **Electronic Control System.** 6-page illustrated Data Release A-703 describes components, features, and typical applications of new "Autronic" electronic control system for industrial processes.—The Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio.

U-524 **Pneumatic Control Unit.** 8-page Bulletin 5452 describes improved design of maker's "Ratio Totalizer" for combining input control pressure and spring forces, and producing an output control pressure based on addition, subtraction, multiplication, division or more complicated functions of input control signals.—Hagan Corp., P. O. Box 1346, Pittsburgh 30, Penna.

U-525 **Air-system Control.** 24-page brochure A.I.A. File No. 30-F-2 covers instrumentation of industrial air-handling systems. Includes analysis of different systems, modes of control, typical specifications, and operational factors.—Minneapolis-Honeywell Regulator Co., Minneapolis 8, Minn.

U-526 **Machine and Process Control.** 8-page Selection Guide GEA-5781 contains quick-reference selection data, photographs, and listings of motor starters, relays, limit switches, photoelectric relay, electronic timer, electronic relay, pressure and vacuum switch, float switch, pressure governor, and smoke-density control.—General Electric Co., Schenectady 5, N. Y.

Optical

U-527 **Surveying.** 12-page catalog entitled "Leveling Instruments" describes theodolites, compasses and alidades made by Breithaupt in Germany.—Columbia Technical Corp., 5 E. 57th St., New York 22, N. Y.

U-528 **Colorimeter and Turbidimeter.** 2-page Catalog 925 illustrates and describes principles, features, and operation of new "Chromatron" photoelectric colorimeter and turbidimeter for analysis and control.—Hellige, Inc., 3718 Northern Blvd., Long Island City 1, N. Y.

U-529 **Interference Filters.** 16-page Bulletin 180 contains principles and application of new narrow-band "G.A.B." interference filters for colorimetry, fluorimetry, microscopy, photometry, densitometry, etc. Includes discussion and survey of filter theory and types.—Photovolt Corp., 95 Madison Ave., New York 16, N. Y.

U-530 **Narrow-band Filters.** 2-page Bulletin NBF 339 describes new "Schott Narrow Band Interference Filters" with closely-controlled peaks and half-band widths.—Fish-Schurman Corp., 70 Portman Road, New Rochelle, N. Y.

U-531 **Comparator.** 4-page Form K1 illustrates and describes new "Model C-100" vertical optical comparator with 16-inch screen and convenient "swing-away" stage assembly.—Portman Instrument Co., 6 Manhasset Ave., Port Washington, N. Y.

U-532 **Optical Gaging.** 4-page publication, "Optical Gaging," describes elements of an optical gage and the charts used in inspection; outlines staging fixture principles and desirable characteristics in an optical gaging projector.—Industrial Optical Sales Div., Eastman Kodak Co., Rochester 4, N. Y.

U-533 **Cleaning Precision Optics.** 6-page booklet (price 25 cents) describes, with illustrations, method used at government arsenal in assembly of precision army optical instruments.—Edmund Scientific Corp., 101 E. Gloucester Pike, Barrington, N. J.

U-534 **Adjustments of Alidades.** 28-

Another Important Instrumentation Development by Beckman . . .

- ✻ Greater Compactness
- ✻ Higher Accuracy
- ✻ Lower Sample Consumption
- ✻ Maximum Convenience

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To meet the steadily growing interest in flame spectrophotometric methods, Beckman engineers have developed a new Flame Photometry Attachment that sets greatly advanced standards of compactness, convenience, accuracy and simplicity.

Used with the Beckman "DU" Spectrophotometer and standard oxy-hydrogen or oxy-acetylene equipment, it combines the unusually high accuracy and resolution of the well-known Beckman "DU" with the conveniences of flame spectrophotometric methods, providing an instrument capable of the quantitative determination of more than 40 elements, including heavy metals and rare earths, as well as the alkali metals.

The atomizer-burner of this new instrument is much smaller, simpler and more trouble-free than previous designs. It incorporates a straight, large-diameter, noble-metal atomizer tube discharging directly into the flame, and will spray even cloudy or highly concentrated solutions indefinitely without clogging or "drifts."

Other important features of this new Beckman development are outlined at right. Best of all, this new instrument is available at a new low price for equipment of this quality. Your nearest authorized Beckman Instrument dealer will gladly supply full details—or write direct!

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Illustration at right shows atomizer-burner actual size.

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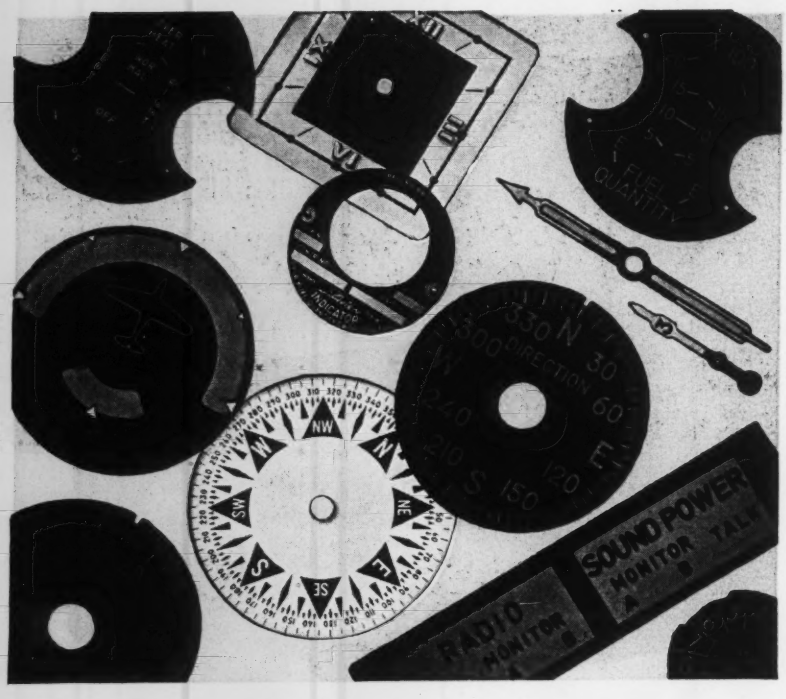
Outstanding Features of the New Beckman Flame Photometry Attachment

- Sample beaker is supported in a unique mechanism that swings the beaker outside the case for easy filling, or swings it back into position below the burner tube. Further, as the beaker is raised into position below the burner, it automatically tips so that sample solution is drawn from lowest point in beaker. Thus, complete analyses can be made with even extremely small samples.
- The atomizer requires only about 2 ml of sample solution per minute, and a sample of 1 to 3 ml is ample for determination of several constituents.
- Fuel consumption is very low—about 5 cu. ft./hr. for acetylene, 8 cu. ft./hr. for oxygen, 20 cu. ft./hr. for hydrogen.
- The hot flame, coupled with the high resolution of the "DU" Spectrophotometer, permits unusually narrow band widths to be used—less than 10 millimicrons for most determinations. Accuracies of 0.5% or better are obtainable.
- Sample concentration is unimportant (provided it is above the lower detectable limit) permitting maximum versatility and convenience in making analyses.
- Although the sensitivity of most elements is improved when the elements are in water solution, non-aqueous solutions are as easily handled as water. Even combustible solvents can be used—and in fact, organic solvents frequently increase sensitivity of the readings.
- The atomizer-burner, sample-positioning device, focusing mirror and adjustments are all unitized into a compact, cast-metal housing. All necessary regulators and gauges (except standard regulators on fuel and oxygen tanks) are conveniently mounted on a separate control panel.

For complete details on this Beckman advancement, write for Data File 31-47.



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NEW LITERATURE

page pocket-size "Service Booklet C" contains basic information on stadia surveying in addition to detailed instructions.—W. & L. E. Gurley, Troy, N. Y.

Speed and Freqency

U-535 **Stroboscope.** 1-page Bulletin B-18A describes new "Labstrobe," an inexpensive 60-cycle stroboscope.—Berkshire Labs., 550 Beaver Pond Rd., Lincoln, Mass.

U-536 **Aperiodic Stroboscope.** 24-page Pamphlet SS 486 illustrates and describes Swiss-made "Super-Stroboscope" for periodic and aperiodic phenomena. Includes principles and operation.—Lovins Engineering Co., 8203 Cedar St., Silver Spring, Md.

U-537 **Frequency Measurements.** 4-page Vol. 8 No. 1 issue of "Biddle Instrument News" features the applications of Frahm resonant-reed frequency meters.—James G. Biddle Co., 1316 Arch St., Phila. 7, Penna.

U-538 **Tachometers.** 2-page Technical Data Sheet No. 42P describes tachometers for applications where a wide range of speed measurement is desired in a continuously-indicating switchboard instrument.—Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

U-539 **Gear Train.** 6-page illustrated brochure gives detailed specifications of maker's new precision gear trains.—Bowmar Instrument Corp., 4214 Leo Rd., Fort Wayne, Ind.

U-540 **Variable-speed Transmissions.** 4-page bulletin describes maker's line of "Zero-Max transmissions" capable of instant neutral and instant reverse.—Revco Inc., 2 E. Franklin St., Minneapolis 4, Minn.

U-541 **Balancing Machines.** 2-page bulletin gives specifications of horizontal and vertical machines for balancing rotating parts; also various attachments.—R. B. Annis Co., Indianapolis 2, Ind.

Recorders and Planimeters

U-542 **Graphic Recorders.** 16-page "Case No. 12" of pocket-size series on "Solving Industrial Crimes" tells of use of a time recorder in a municipal filtration plant and in other plants for monitoring schedules.—The Esterline-Angus Co., Indianapolis, Ind.

U-543 **X-Y Recorder.** Leaflet announces and gives specifications of new "Autograf" general-purpose two-variable recorder which plots automatically on rectangular coordinates.—Frank L. Moseley, 1136 No. Las Palmas Ave., Los Angeles 38, Calif.

U-544 **Recording Gastrointestinal Functions.** 4-page No. 21 issue of "Instrument Notes" features article on work at U. of Southern California School of Medicine on multichannel recording of gastrointestinal functions. Includes principles and instruments.—Statham Laboratories, Inc., 12401 W. Olympic Blvd., Los Angeles 64, Calif.

U-545 **Planimeters and Adapter.** 4-page bulletin describes "Lasico Square Root Planimeter" for circular charts of flowmeters, etc.; 4-page bulletin describes "Lasico Radial Planimeter" for circular charts with linear ordinates; 2-page bulletin describes "Lasico Universal Linear Planimeter Adapter" for extending usability of standard planimeters.—Los Angeles Scientific Instrument Co., 108 W. 6th St., Los Angeles 14, Calif.

Chemical Laboratory

U-546 **Laboratory Equipment.** 30-page May issue of "The Welch Physics and Chemistry Digest" covers laboratory equipment, such as gas burners, capacitance boxes, tesla coils, etc. Includes reviews of novel classroom experiments.—W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill.

U-547 **Laboratory Equipment.** 20-page No. 52-3-46 issue of "Eberbach Announcer" features articles on national institutes of health, the "Dyna-Cath" dual mercury cathode, heating tape, induction heater, and other laboratory equipments.—Eberbach & Son Co., Ann Arbor, Mich.

U-548 **Laboratory Equipment.** 16-page issue No. 15 of "What's New for the Laboratory" features items on adjustable thermometers, glass tubing manipulator, "Mighty Midget" stirrer, Coleman, Beckman and Precision Instruments, vacuum pump, and sectional metal furniture.—Scientific Glass Apparatus Co. Inc., Bloomfield, N. J.

U-549 **Laboratory Instruments and Accessories.** Set of six bulletins and circulars (all in English) illustrate and describe Reichert and Jung instruments: "Kofler Hot Bench"; Kofler Lo Temp Hot Bench"; microtome "HE" for electron microscopy; Microtome "K" for metal cutting; camera microscope; and polarimeters.—William J. Hacker & Co., Inc., 82 Beaver St., New York 5, N. Y.

U-550 **Electron Microscope.** 24-page brochure illustrates and describes typical applications of the electron microscope in various industries.—Radio Corp. of America, Engineering Products Dept., Camden, N. J.

U-551 **Custom Scientific Glassware.** 12-page brochure illustrates and describes maker's facilities and products of scientific glassware. Includes special sheet for ordering custom-made glassware.—Wakefield Industries, Inc., 5108 Grove St., Skokie, Ill.

Chemical Process Analysis

U-552 **Infrared Analyzer.** 4-page Bulletin 0705-1 describes "MSA Infra-Red Gas and Liquid Analyzer" for measuring concentrations as low as 2 ppm. with less than 2 percent full-scale drift per day.—Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh 8, Penna.

U-553 **Raman Equipment.** 4-page March-April 1952 issue of "Spectrographer's News Letter" features a description of maker's new "Model 9000 Raman Quantometer."—Applied Research Labs., Glendale 5, Calif.

U-554 **Spectrochemical Standards.**

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NEW LITERATURE

64-page May issue of "General Electric Review" features articles on preparation of electrochemical standards, punched cards, color TV, nitrile rubber gaskets, mica mat, and others.—General Electric Co., Schenectady, N. Y.

Viscosity

U-555 **Viscosity Measurement.** Advance bulletin illustrates and describes new "Ultra-Visconson" for measuring viscosity by use of ultrasonics. Includes features, characteristics, and performance graphs.—Rich-Roth Laboratories, 673 Connecticut Blvd., E. Hartford 8, Conn.

Inspection and Testing

U-556 **Surface Roughness Measurement.** 4-page bulletin describes a new portable surface comparator designed for point-of-production use, with a range of 0 to 100 microinches rms.—Kota-Meters, Inc., 2311 Burbank St., Dallas 19, Texas.

U-557 **Metals Tester.** 1-page Bulletin B-44 describes a new type of instrument for testing ferrous and nonferrous metals for heat treatment, composition, etc., by electromagnetic means.—Berkshire labs., 550 Beaver Pond Rd., Lincoln, Mass.

U-558 **Gage Blocks.** 8-page 1952 edition of gage block catalog illustrates and describes complete lines of "Lifetime" carbide and steel gage blocks. Text stresses "Precision in Millionths" and machine-lapping process called "Ultra-Finish."—The Fonda Gage Co., Inc., 59 Daly St., Stamford, Conn.

U-559 **Master Balls.** 1-page Bulletin 522 announces two new sets of precision balls (gage-block accuracy) for toolroom and gaging equipment.—Industrial Tectonics Inc., 3684 Jackson Rd., Ann Arbor, Mich.

Valves

U-560 **Diaphragm-motor Valves.** 4-page Bulletin 513 describes new "Class DV" double-seated diaphragm-motor control valves with "Flow-Line Contoured Body" and standard ISA face-to-face dimensions.—Leslie Co., 225 Delafield Ave., Lyndhurst, N. J.

U-561 **Safety Valves.** 1-page bulletin entitled "Your Safety Valves Can Be Booby Traps" points out protective features of "BalanSeal Safety-Relief Valve."—Farris Engineering Corp., 436 Commercial Ave., Palisades Park, N. J.

U-562 **Air Valves.** 8-page Bulletin 231 describes new line of "Pilot-Master" 2-way, 3-way and 4-way valves for air pressures to 150 psi. in sizes from 0.375 to 1.25 in.—Hannifin Corp., 1101 S. Kilbourn Ave., Chicago 24, Ill.

U-563 **Solenoid Valves.** 4-page bulletin describes maker's solenoid-operated pilot-controlled 3-way and 4-way valves in sizes from 0.25 in. to 1.25 in. pipe sizes.—Ross Operating Valve Co., 120 E. Golden Gate Ave., Detroit 3, Mich.

U-564 **Air Valves.** 8-page Bulletin No. 303A describes in detail "600 Series" and "880 Series" hand and foot 3-way and 4-way valves; also handles and treadles.—Ross Operating Valve Co., 120 E. Golden Gate, Detroit, Mich.

U-565 **Air Valves.** 1-page leaflet displays maker's line of hand, foot, cam, solenoid and pilot-controlled valves for air-operated equipment.—Mechanical Air Controls, Box 5171 Southfield Station, Detroit 35, Mich.

Telemetering and Communication

U-566 **Telemetering.** 18-page illustrated booklet covers maker's large line of telemetering receiving stations. Includes construction, operation, and components.—Development Laboratories, Pacific Div., Bendix Aviation Corp., Burbank, Calif.

U-567 **Business Telephone Systems.** 8-page Circular 1735 illustrates and describes P-A-X business telephone systems for intercommunication—Automatic Electric Sales Corp., 1033 W. Van Buren St., Chicago 7, Ill.

U-568 **Carrier-system Filter Testing.** 8-page April issue of "The Lenkurt Demodulator" features 4-page article on locating trouble in carrier-system wave filters. Also material saving in carrier systems.—Lenkurt Electric Co., San Carlos, Calif.

Computing Equipment

U-569 **Automatic Data Analysis.** 12-page illustrated brochure gives features of maker's line of automatic data analyzers—"Telereader," "Telecorder," and "Teleplotter." Includes vital data and applications.—Telecomputing Corp., Burbank, Calif.

U-570 **High-speed Data Printer.** 4-page Descriptive Bulletin N-1 announces new "Synchroprinter" which prints 600 characters per second for analog and digital computers.—ANelex Corp., Concord, N. H.

Vibration and Sound

U-571 **Sound-survey Meter.** 12-page April issue of "The General Radio Experimenter" illustrates and describes new portable sound-level meter. Includes features and operation.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-572 **Vibration and Noise Tester.** 4-page bulletin describes new "Electro Probe," a low-cost trouble-spotter which utilizes a pointed pick-up and a 3-stage amplifier, and which indicates both visually and audibly.—Erwood Inc., 1770 Berteau St., Chicago 13, Ill.

Industrial Television

U-573 **Industrial Television.** 4-page illustrated Bulletin 1025-A covers components, features, advantages, and typical applications of maker's new "Model 300-B Utiliscope" (wired TV unit) for industry.—Diamond Power Specialty Corp., Lancaster, Ohio.

Continued on next page

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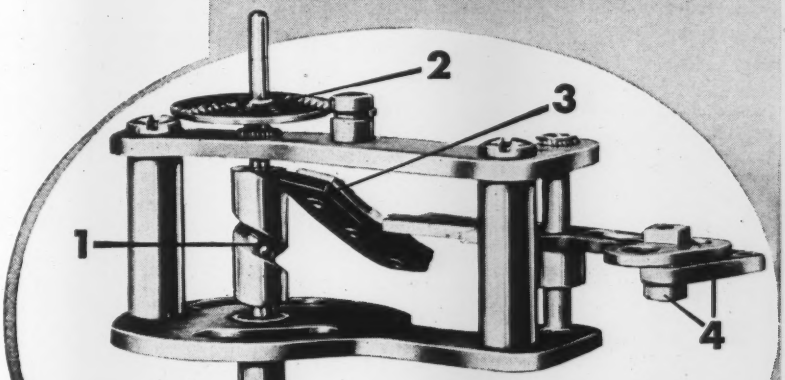

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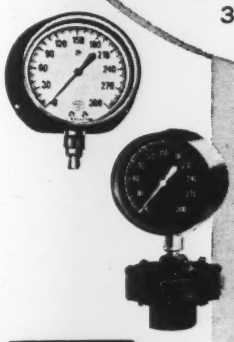

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NEW LITERATURE

Electrical & Electronic Test Instruments

U-574 Test Instruments. 4-page bulletin describes power supplies, strobotachometer, VTVM, frequency-shift keyer, and master oscillator. Includes specifications.—Electronic Measurements Co., Red Bank, N. J.

U-575 Vacuum-tube Voltmeters. 4-page Bulletin II-231-A describes and gives specifications of three new VTVM's (low-, medium- and high-frequency), all covering wide ranges.—Millivac Instrument Corp., P. O. Box 997, Schenectady, N. Y.

U-576 Vacuum-tube Electrometers. 8-page illustrated bulletin describes maker's VT electrometers and gives application diagrams of 17 basic uses. Includes features and specifications.—Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio.

U-577 Volt-ohm-milliammeter. 8-page April issue of "The Tripletter" describes maker's VOM and uses of maker's products in the Hastings "Twin Meter."—The Triplett Electrical Instrument Co., Bluffton, Ohio.

U-578 Oscillography. 20-page Vol. 13 No. 1 issue of "The Oscillographer" features 12-page article on "Techniques of Measurement In Oscillography." Also UHF measurements and new "Type 304-HR" CRO.—Allen B. DuMont Laboratories, Inc., 1500 Main Ave., Clifton, N. J.

U-579 Electronic Test Instruments. 138-page illustrated general catalog covers maker's line of attenuators, switches, resistors, potentiometers, test equipment, and components. Includes principles of operation and detailed specifications.—The Daven Co., Newark, N. J.

U-580 Test Probes. 16-page April issue of "CD Capacitor" features article on various probes useful in trouble shooting circuits.—Cornell-Dubilier Electric Corp., Hamilton Blvd., S. Plainfield, N. J.

U-581 D-c. Millivoltmeter. 2-page leaflet describes "Model 200-A" for converting d-c. input (down to microvolts) into amplified sinoidal alternating voltage output. Also for measuring currents down to 10^{-12} amps.—Industrial Control Co., Wyandanch, L. I., N. Y.

U-582 Pulse Generator. 1-page Bulletin B-1A describes new "Labmarker," an instrument useful for timing purposes in cathode-ray oscillography.—Berkshire Labs., 550 Beaver Pond Rd., Lincoln, Mass.

U-583 Aircraft Circuit Tester. 4-page Bulletin 94 describes new "Nacelle Tester" which can check resistance of up to 100 circuits in eight seconds.—Bogue Electric Mfg. Co., Paterson 3, N. J.

U-584 Motor Tester. 4-page bulletin describes new German-made instrument for detecting faults and preventing breakdowns in electrical machinery.—Columbia Technical Corp., 5 E. 57th St., New York 22, N. Y.

U-585 **Snap-around Volt-ammeters.** 4-page Catalog No. 128 and 16-page pocket-size Manual No. 504 describe maker's "Amprobe" instruments and how to do numerous routine and special service jobs with them.—Pyramid Instrument Corp., Lynbrook, N. Y.

U-586 **Multi-range Instrument.** 4-page bulletin describes new "Model 8 Avometer" with a total of 25 d-c. and a-c. ranges.—British Industries Corp., 164 Duane St., New York 13, N. Y.

U-587 **Standard A-c. Instrument.** 4-page Vol. 19 No. 3 issue of "Electrical Measurements" features "Model DYP Dynamometer Polyranger" with 0.3-percent accuracy on twenty voltage and current ranges.—Sensitive Research Instrument Corp., 9-11 Elm Ave., Mount Vernon, N. Y.

U-588 **Multi-function Instrument.** 2-page catalog insert describes new "VAW Meter" for measuring volts, amperes, and watts from 20 to 20,000 cps.—John Fluke Engineering Co., Box 755X, Springdale, Conn.

U-589 **Electronic Servicing.** 24-page March issue of "Successful Servicing" features articles on TV horizontal output transformers and interpretation of oscilloscope waveforms. 24-page April issue covers technique of TV servicing with special probes.—John F. Rider, Publisher, Inc., 480 Canal St., New York 13, N. Y.

Power Supplies

U-590 **Power Supplies.** 18-page illustrated brochure describes maker's large line of regulated power supplies, including specifications.—Kepco Laboratories, Inc., 131 Sanford Ave., Flushing 55, N. Y.

U-591 **Frequency Changers and Controllers.** 8-page Vol. 5 No. 2 issue of "Currently" features announcement of new frequency changers and controllers with 400-cps. and 60-cps. outputs for airborne and industrial uses. Also descriptions of high-current wide-range "Nobatron Rangers."—Sorensen and Co., 357 Fairfield Ave., Stamford, Conn.

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U-592 **Components and Instruments.** 48-page Supplement 130 illustrates and describes hundreds of electronic test instruments and components han-

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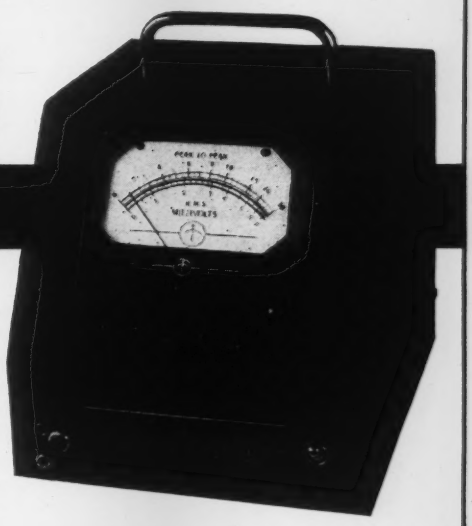

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NEW LITERATURE

dled by large distributor.—Allied Radio, 833 W. Jackson Blvd., Chicago 7, Ill.

U-593 **Resistors.** Page 1 of Catalog D-130 Supplement describes and lists "Axiohm" 5- and 10-watt vitreous enamel wire-wound miniature resistors.—Ward Leonard Electric Co., Mount Vernon, N. Y.

U-594 **Suppression Capacitors.** 6-page Bulletin No. 651 describes in detail maker's new feed-through type of suppression capacitors; contains eight graphs of characteristics.—Stupakoff Ceramic & Mfg. Co., Latrobe, Penna.

U-595 **Piezoelectric Crystals.** 16-page illustrated Bulletin 43 contains specifications, index for military crystals, temperature characteristics, and theoretical data on maker's large line of quartz piezoelectric crystals.—Bliley Electric Co., Union Station Bldg., Erie, Penna.

U-596 **Displacement Pickups.** 12-page Bulletin R-31 explains principles and characteristics of "differential transformer" or "linear transducer" pickups; also instruments which embody these devices.—Automatic Temperature Control Co., 5200 Pulaski Ave., Phila. 44, Penna.

U-597 **VHF Power Tetrode.** 12-page bulletin describes new "6166" forced-air-cooled tetrode with 10-kw. max. plate dissipation.—Tube Dep't, Radio Corp. of America, Harrison, N. J.

U-598 **Miniature Pulse Transformer and Delay Lines.** 4-page Technical Bulletin PT-52-2 covers specifications, characteristics, and applications of maker's miniature pulse transformer MPT 101-B. 4-page Bulletin DDL-51-8 covers miniature distributed-constant delay lines.—PCA Electronics, Inc., 6368 DeLongpre Ave., Hollywood 28, Calif.

U-599 **Potential Transformers.** 36-page 1st quarter, 1952 issue of "Electrical Review" contains technical articles on potential transformers, circuit breakers, and safeguarding large a-c. motors.—Allis-Chalmers Electrical Review, Milwaukee 1, Wis.

U-600 **Multi-contact Connectors.** 4-page April issue of "Amphenol Engineering News" contains six articles on uses of maker's connectors and cables in recently-announced instruments.—American Phenolic Corp., 1830 S. 54th Ave., Chicago 50, Ill.

U-601 **Electrical Connectors.** 6-page bulletin describes and gives drawings and specifications of miniature precision connectors for instrumentation uses.—DeJur Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y.

U-602 **Rack and Panel Connectors.** 8-page Catalog Supplement No. 1 describes maker's new line of connectors for electronic and aircraft use; includes dimensional drawings.—Hugh H. Eby, Inc., 4700 Stenton Ave., Phila., Penna.

U-603 **Transmission Lines and Waveguides.** 88-page publication "Survey of Radio-Frequency Transmission Lines and Wave Guides" by E. S. Win-

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lund contains historical survey, technical data, and extensive bibliography. Price $1.50.—The Radio Club of America, 11 West 42nd St., New York 18, N. Y.

U-604 **R-f. Transmission Losses.** 8-page May issue of "The Lenkurt Demodulator" features article on principles and methods of calculating transmission loss in UHF radio links. Includes typical calculation.—Lenkurt Electric Co., San Carlos, Calif.

U-605 **Hermetically Sealed Relay.** 4-page Bulletin GEA 5729 describes new "CR 2791 G" 4-p.d-t. 28-v. 3-amp. relay for aircraft, marine and portable applications.—General Electric, Schenectady, N. Y.

U-606 **Waveguide Directional Coupler.** 4-page March-April issue of "hp Journal" features a description of a precision directional coupler using multi-hole coupling.—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

U-607 **Kinescope Magnets.** 4-page Bulletin AN-152 discusses design and adjustment considerations for kinescope centering and ion-trap magnets.—Tube Dept., Radio Corp. of America, Harrison, N. J.

Tools and Supplies

U-608 **Tools and Supplies.** 10-page brochure is index of tools, supplies, and equipment for precision manufacturing handled by large distributor. Also cross-index of agencies.—R. P. Gallien & Son, 220 W. 5th St., Los Angeles 13, Calif.

U-609 **Flaring Tool.** 2-page Bulletin No. 3003 describes "No. 500-F Rol-Air" tool for rolling 45-degree SAE flares; suitable for soft copper, aluminum and brass tubing in six sizes.—The Imperial Brass Mfg. Co., 1200 W. Harrison St., Chicago 7, Ill.

U-610 **Imported Tools.** 4-page brochure lists 54 imported tools and 62 mixed-material assortments useful for precision manufacturing and available at reduced price.—Modern Technical Supply Co., 55 W. 42nd St., New York 36, N. Y.

U-611 **Tube Fittings.** 24-page illustrated Catalog E-1457-A gives features, specifications, and typical applications of maker's line of "Ermeto" steel and stainless-steel tube fittings that require no flaring, threading, welding, or soldering.—The Weatherhead Co., Industrial Div., 300 E. 131st St., Cleveland 8, Ohio.

U-612 **Welding and Soldering Aluminum.** 2-page technical bulletin and 2-page reprint of a magazine article, describe new "Chemalloy" and its uses in joining aluminum and other difficult metals.—Chemalloy Associates, Santee, Calif.

U-613 **Written-labels Tape.** 4-page Form No. 5 describes "Labelon" pressure-sensitive tape suitable for pencil, stylus, or typewriter, available in various widths and colors.—Industrial Products Engineering Co., 26-40 Jackson Ave., Long Island City 1, N. Y.

TRIGGER-TRIP TIME DELAY RELAYS

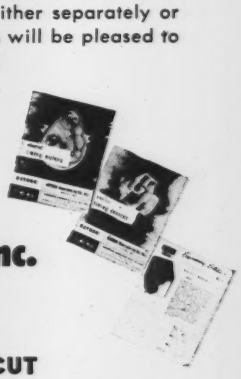
for 60 and 400 cycle A.C., also D.C.

The **HAYDON*** 5103 time delay relay is designed so that the synchronous motor performs its true function as a time standard. Switching work is accomplished by a relay coil, which, when energized, triggers the load switch for release at the end of the delay time. Hair trigger release point assures snap action.

HAYDON specializes in the manufacture of timing components for standard applications and also in the design and mass production of custom-engineered timers for volume applications. The basic element of all HAYDON timers is our own rugged industrial motor. This means that HAYDON timing devices can be depended upon to give long, quiet operation. They are small and compact and offer designers unusual latitude in that they may be mounted and will operate in any position. For military applications various motors are available either separately or in many types of timers; HAYDON engineers will be pleased to review your requirements and specifications.

COMPLETE INFORMATION
Write for literature you need: catalogs on motors or devices; bulletins on D. C. motors, 400 cycle motors, time delay relays.

*TRADEMARK REG. U. S. PAT. OFFICE



HAYDON Manufacturing Co., Inc.

Subsidiary of GENERAL TIME CORPORATION

2030 ELM STREET

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